CONTENTS AND INDEX

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THE GEOLOGICAL SURVEY OF INDIA,

VOLS. I TO X—1868-77.

LIST OF AUTHORS AND PAPERS.

OLDHAM, T.—Meteorites, vol. ii, p. 101.

" Annual Report of the Geological Survey of India and of the Museum of Geology, Calcutta, for the year 1869, vol. iii, p. 1.

" The Wardha river coal-fields, Berar and Central Provinces, vol. iii, p. 45.

" Meteorites, vol. iii, p. 104.

" Annual Report of the Geological Survey of India and of the Museum of Geology, Calcutta, for the year 1870, vol. iv, p. 1.

" On the supposed occurrence of native antimony in the Straits Settlements, vol. iv, p. 48.

" On the composition of a deposit in the boilers of steam-engines at Raniganj, vol. iv, p. 48.

" Sketch of the geology of the Central Provinces, vol. iv, p. 69.

" Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1871, vol. v, p. 1.

" Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1872, vol. vi, p. 1.

" Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1874, vol. viii, p. 1.

" Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1875, vol. ix, p. 1.

STOEHR, DR. EMIL.—The copper mines of Singbhúm, (*translated from* the Vierteljahrschrift, der naturforschenden Gesellschaft, Zurich, vol, v, p. 329, 1860; and the Neues Jahrbuch fur Min. Geo. u. Pal.. 1864) vol. iii, p. 86.

STOLICZKA, DR. F.—Additional observations regarding the cephalopodous fauna of the South Indian cretaceous deposits, vol. i, p. 32.

" General results obtained from an examination of the gastropodous fauna of the South Indian cretaceous deposits, vol. i, p. 55.

" Note on *Pangshura tecta* and the other species of *Chelonia* from the newer tertiary deposits of the Nerbudda Valley, vol. ii, p. 36.

" A brief account of the geological structure of the hill-ranges between the Indus Valley in Ladák and Sháh-i-dula on the frontier of the Yárkand territory, vol. vii, p. 12.

" Geological notes on the route traversed by the Yárkand Embassy from Sháhi-dula to Yárkand and Káshgar, vol. vii, p. 49.

" Note regarding the occurrence of jade in the Karakásh Valley, on the southern borders of Turkistán, vol. vii, p. 51.

" Geological observations made on a visit to the Chaderkul, Thian Shan range, vol. vii, p. 81.

" Note on the Pámir, vol. vii, p. 86.

" The Altum-Artush considered from a geological point of view, vol. viii, p. 13.

THEOBALD, JUNR., W.—On the beds containing silicified wood in Eastern Prome, British Burmah, vol. ii, p. 79.

" On the alluvial deposits of the Irawadi, more particularly as contrasted with those of the Ganges, vol. iii, p. 17.

" On petroleum in British Burmah, &c., vol. iii, p. 72.

" The Axial group in Western Prome, British Burmah, vol. iv, p. 33.

" A few additional remarks on the Axial group of Western Prome, vol. v, p. 79.

" Note on the value of the evidence afforded by raised oyster banks on the coasts of India, in estimating the amount of elevation indicated thereby, vol. v, p. 111.

" A brief notice of some recently discovered petroleum localities in Pegu, vol. v, p. 120.

" Notes of a celt found by Mr. Hacket in the ossiferous deposits of the Narbada Valley (pleiocene of Falconer): on the associated shells, vol. vi, p. 54.

INDEX.

C

D

H

L

Q

R

W

Y

Z

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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1876. [May.

THE RETIREMENT OF DR. OLDHAM.

THIS number of our Records would be sadly wanting without a word of grateful farewell to the man who has conducted the labours of the Geological Survey of India from their beginning until now. When Mr. Oldham came to India in 1851, the Geological Survey cannot be said to have existed. Some coal-viewers and improvised geologists had made occasional reports to Government, but there was nothing that could be called an institution, either as to staff or abiding-place. Professor Oldham conferred at once upon his post the influence of a well-known name, and the experience he had for years acquired as Director of the Geological Survey of Ireland. With those guarantees, by personal address and energy, he quickly acquired the confidence of Government, and by its liberal support he was able rapidly to bring together an efficient body of working geologists, with, and through whom he soon began to throw light upon the rocks of India. Of the value of his services, as exhibited in the publications of the Survey, Dr. Oldham has repeatedly received very high testimony from the scientific world. To appreciate fully what he has effected, one should have experience of the position, where every means, material and personal, had to be formed or imported; and further, one should see what is only known to those present, the very valuable library and the extensive collections brought together by his care. Due honour paid to the intelligent liberality of the Government of India, it is to Dr. Oldham, whether as Superintendent of the Geological Survey, or as President of the Asiatic Society of Bengal, more than to any other man, that Calcutta owes the magnificent museum-building it can now boast of. All this he now leaves to his colleagues and successors. Failing health compels him to retire from the service, and leave the country before he could give form and unity to his labours. Those who reap where he has sown should ever remember the great debt they owe to Dr. Oldham.

NOTES ON THE AGE OF SOME FOSSIL FLORAS OF INDIA, *by* OTTOKAR FEISTMANTEL, M. D., *Geological Survey of India.*

I AND II.

WHILE preparing detailed descriptions and investigations of the several fossil floras of India, with drawings of all the most important specimens for the Palæontologia Indica, I think it best to give brief outlines in this place of the results I have obtained from the study. Though persuaded of their interest, both general and special, I must not presume that every naturalist can and will take the time and trouble to study those detailed investigations. All may, however, easily master the results if offered to them in this short form.

It is necessary to preface these papers with a notice of the formations to which they refer. The best known, because almost the only fossiliferous, rock-series in the peninsular area of India, is that usually spoken of collectively as the plant-bearing series. This is an awkward designation; and I will at once adopt instead the name GONDWÁNA series or system, to be understood in the same wide sense as when we speak of the Jurassic or Silurian series or system. The name was proposed some years ago by Mr. Medlicott, and has since been more or less current on the survey; it has been once used in print by Mr. H. F. Blanford in his little work on the Physical Geology of India. We have in India important coal-bearing strata of cretaceous and nummulitic age, quite distinct from the Gondwána series, to the flora of which we will first call attention in these papers as of more pressing interest.

From Raniganj, on the western edge of the Delta of the Ganges, these formations stretch in detached basins up the valley of the Damuda, between the crystalline masses of Chutia Nagpur and Hazaribagh. Smaller patches also occur on the northern portion of the latter area, in some of the valleys, and along the border of the gneiss towards the plains of the Ganges. The Rajmahal area belongs to this position. From the head of the Damuda they stretch into the valley of the Sone, spreading out there into the wide basin of South Rewah. A narrow band of the topmost group, passing by Jabalpur, connects this area, across the gneissic mass forming the watershed of the peninsula, with the large basin in the Satpura range, on the west side of which, along the Moran river, the stratified series passes in force beneath the trap rocks of the Deccan. Some few inliers have been detected beneath the trap further to the west in the Narbada valley, as about Barwai. Throughout the entire course along the Sone and Narbada valleys, the boundary of the Gondwána series runs close to the great Vindhyan plateau, from the scarp of which it is everywhere separated by a varying belt of gneissic or schistose rocks.

Far removed to the west, but still within the rock-area of the Indian peninsula, plant-bearing beds of the Gondwána age have long been known to occur in Kach.

This northern region of the Gondwána deposits, stretching obliquely across India from east-north-east to west-south-west, has two extensions to the south. The South Rewah basin is continuous across the watershed of the Sone and Mahanadi rivers, through Sirgujah into Raigarh and Hingir, towards the Talchir coal-field and the Atgarh area below Katák. On the west, in the Satpuras, the Gondwána rocks occupy the watershed between the Narbada and the basin of the Godavari. It is doubtful whether they were ever continuous in this direction, but they here at least come into proximity to the deposits of the same age at Nagpur, and extending from here down the valleys of the Wardah and Godavari to Rajamandri. From the Delta of the Godavari there occur detached patches of these rocks along the coast of the Karnatik to Trichinopoli, fringing the great expanse of gneissic rocks forming the high land of the interior.

There is only one extra-peninsular region in India where rocks of this age have been identified—along the base of the Eastern Himalaya, in Sikhim and Upper Assam.

The following table exhibits the various groups into which the Gondwána series is at present tentatively divided in the several regions :—

Bengal.	South Rewah.	Satpura.	Godavari.	Karnatik.	Kach.	E. Himalaya.
Rajmahal.	Jabalpur.	Jabalpur.	Rajmahal.	Rajmahal.	Kach.	
		Mahadeva.				
Panchet.		Almod.				
DAMUDA. Raniganj.	Pali.	Bijori.	Kamthi.			
DAMUDA. Ironstone shales.		Motur.				
DAMUDA. Barakar.	Barakar.	Barakar.	Barakar.			Damuda
Talchir.	Talchir.	Talchir.	Talchir.			
Gneiss.	Gneiss.	Gneiss.	Vindhyans and gneiss.	Gneiss.		

Most of these strata contain only plant remains. Some widely separated localities have also yielded a few vertebrate fossils of fish and reptiles, for which various ages have been assigned—palæozoic, triassic, and liassic. It is only in Kach and on the east coast of the peninsula that the *upper members* of the series are found associated with beds containing a well-marked marine molluscan fauna; and these have been taken to give the horizon of these groups. The plant beds of Kach alternate with and overlie strata having an upper jurassic fauna; and a similar association of the Rajmahal group has been found near Rajamandri and in parts of the Karnatik. While, at Trichinopoli, plant beds of about the same horizon underlie the well-known upper cretaceous rocks of that region. The evidence of the plants will be seen to indicate a much lower homotaxeous position for these strata; thus establishing a marked palæontological discordance between the marine and terrestrial organisms of this geological epoch in this region. In such cases we must only say, the flora of this or that locality (or stratum) is of such an age, and was still growing on the coast, when already a younger fauna (but of the same epoch) was living in the sea. This is the only way to explain these so-called palæontological contradictions between the fauna and flora of the same strata.

My examination of the collections has so far indicated the existence of five distinctive floras in the following horizons of the Gondwána system :—

1.—Kach (in Kach).

2.—Rajmahal (in different places).

3.—Panchet (in different places).

4.—Damuda (in different places), including the Raniganj (Kamthi), Iron-Shale, and Barakar groups.

5.—Talchir.

It is, of course, possible that further research may necessitate modifications or additions to this classification. The present papers contain my observations on the flora of the Kach beds, in Kach, and of the Rajmahal group in the Rajmahal Hills, and at Kolapilli in the Godavari district.

I.—Flora of the Kach series (Cutch).

The flora of Kach, in comparison with the animal remains from the same formations, is rather poor, especially in the number of genera and species. There are, however, enough characteristic genera and species for determination of the age of the flora as a whole, though it is not quite so easy to determine the age at each locality with the same accuracy.

For my purpose it will be sufficient and most useful to represent the flora first in a general systematical review, and then may follow the localities with their characteristic species and their probable correlation.

A.—ACOTYLEDONES CRYPTOGAMÆ.

I.—Algæ.

Of this family I have not met with any specimen, but Mr. Morris, in Captain Grant's Geology of Kach, describes a *Fucoides dichotomus,* Morr. Although I am quite unable to form an opinion as to whether Mr. Morris is right or not (because I have not seen the original specimen), I may remark that there is no objection to take it so, as from the same strata of other places (England) *Algæ* are mentioned. I would only add that if it is an *Alga,* it is a *Chondrites,* with the same specific name.

Locality not indicated.

II.—Filices.

Ferns are not very frequent, but some most characteristic genera and species occur. Already in the representatives of this family, we can see the character of the strata. At least we must, on the first view, say that they are Mesozoic, the species may then determine nearer.

1. Order, *Tæniopterides.*

As we will also find in the Rajmahal group, this order is abundantly developed, but represented by some different species. This is the first difference we may notice between these two floras.

In the division of this order, I follow the newest by Mr. Schimper—

a.—Tæniopteris, Bgt., mostly Palæozoic.
b.—Angiopteridium, Schimp. Mesozoic.
c.—Oleandridium, Schimp. Mesozoic.
d.—Macrotæniopteris, Schimp. Mesozoic.
e.—Danaeopsis, Heer.
f.—Danæites, Göppt.

Our species are—

a.—Oleandridium vittatum, Schimp. (*Tæniopteris vittata* Bgt.) Some specimens agreeing quite with Brongniart's drawings and those of Lindley and Hutton, also with those of Young and Bird, Phillips, &c., from the English Oolite (Scarborough), are known from Kukurbit, in a grey sandy clay. It is an important species.

b.—Tæniopteris densinervis, Fstm. The fragment from which this species is made I take to be a real *Tæniopteris,* Bgt.

Locality: Kukurbit.

2. Order, *Pecopterides.*

Some fragments occur; a few of them are of considerable importance.

a.—Alethopteris, Whitbyensis, Göpp. *Pecopteris Whitbyensis,* L. and H., Tab. 134 (Foss. flor. of Great Britain.)

Some fragments of a true *Alethopteris,* Göppt. (leaflets attached by the whole base and connected together), I could only identify with this species, which occurs mostly in the English Oolite, although it has been also found in the Liassic strata. This species is often mentioned in books under the most different synonyms. In my detailed descriptions I have brought them all into the relation I think most correct.

Locality: Doodaee, in a reddish-grey soft clay.

b.—*Pecopteris* (*cyatheides*) *tenera,* Fstm. A small fragment of a pinna I place here, but it is of no special importance.

Locality: the same.

3. Order, *Neuropterides.*

It is with Mr. Schimper that I agree in placing the following genus and species in this order, while by other authors it has been assigned to a quite different order. To discuss this point here would be out of place. The genus is *Pachypteris,* Bgt., which I take in Brongniart's sense, and unite with it some *Sphenopteris* and *Neuropteris* of Phillips, *Dichopteris* of Zigno, and *Scleropteris,* ex. p. Saporta. It is of Jurassic age.

a.—*Pachypteris specifica,* Fstm. There is no doubt that the specimen I have so named belongs to the same genus as Brongniart described. It is very near Brongniart's species of *Pachypteris,* also to *Dichopteris visianica,* Zigno.

These species, with which ours agree, are lower Oolitic (Scarborough and Italy).

Locality: Bhoojooree, in a soft reddish clay.

b.—*Pachypteris brevipinnata.* This form, which I believe to be the same genus, I so name on account of its shorter pinnæ. Locality.—Kukurbit.

4.—Order, *Cyclopterides.*

Genus, *Actinopteris.*

Some peculiar, orbicular, and radially striated forms from Bayreuth M. Göppert, described first as *Cyclopt. peltata,* Göpp., and we find this locality mentioned as Keuper. But later, from the researches of M. Schenk, these localities near Bayreuth (Culmbach, Veithlahm) are determined as belonging to the interposed strata (between Keuper and Lias) called Rhœtic. This species, too, was independently changed into *Actinopteris peltata,* Schnk. I have now found this form in the Kach series. There are three specimens quite agreeing with all the drawings; so I am, no doubt, correct in the identification, although I am still quite unable to say anything distinct about the nature of these fossils. Prof. Schimper regards them as pseudo-fossils, formed by infiltration; but on this supposition their constant form and limited occurrence in the Juro-triassic epoch, most near the division boundary, would be inexplicable.

Locality: Near Gooneri; in gray, sandy clay, as at Kukurbit. If I do not accept this locality to be Rhœtic, I must at least accept this fossil as an indication of a lower horizon than has as yet been assigned to these plant beds.

B.—COTYLEDONES PHANEROGAMÆ.

I.—*Cycadeæ.*

This family, which was in India generally very abundant in the floras of Jurassic times, has the most representatives also in the Kach series. We will, however, see that the representation here is in a different manner than in the Rajmahal beds; and this is another point of difference between these series, which were formerly thought identical.

1.—Genus *Ptilophyllum,* Morr.

I take this name of Morris, and not the later *Palæozamia,* Endl., because our genus is indeed quite different from all others, and therefore also from *Palæozamia,* as Schimper and Saporta have also lately shown.

This *Ptilophyllum* is a truly Indian type, forming the only link between some Indian local floras; and we can ascertain independently that the *Ptilophyllum (Palæozamia)* bearing beds are all of Jurassic (lower) age.*

* It may be well to note that I use the classification making the Jurassic to include Lias.

a.—Ptilophyllum Cutchense, Morr. (*Palæozamia Cutchensis*, Morr. and Oldh.) This is the predominant form, with shorter and more obtuse leaflets. I distinguish several varieties which I need not enumerate here. Locality: Kukurbit and Bhoojooree.

b.—Ptilophyllum acutifolium, Morr. Mr. Morris, in Captain Grant's Geology (Transactions, Geolog. Soc., 1840, Vol. V, 2 Ser., p. xxi, f. 123), figures several specimens, but I have observed only one. Locality: Bhoojooree.

2.—Genus *Otozamites*, Braun.

c.—Otozamites contiguus, Fstm. Some fern-like forms have been formerly placed as *Otopteris;* but I believe it is best to take them all still as *Otozamites*, Braun; it will at least avoid confusion.

The above species is one of those with short *pinnulæ.* Locality: Kukurbit.

d.—Otozamites imbricatus, Fstm. A species with longer *pinnulæ*, which are so inserted on the *rhachis* that they are imbricated. Locality.—Loharia; in ferruginous fine-grained sandstone.

e.—Otozamites cf. *Goldiaei*, Bgt. This is one of the groups with long *pinnulæ;* and I consider our specimen closely allied to Brongniart's species from the English Oolite; and so a species of more importance than the others. Locality.—Kukurbit.

3.—Genus *Cycadites*, Bgt.

f.—Cycadites Cutchensis, Fstm. A very delicate species, with the distinct midrib of *Cycadites.* Very close to *Cycadites zamioides*, Leckenb., differing only by the insertion of the leaflets on the base. This latter is also an Oolitic species from England (Scarborough). Locality: Kukurbit.

4.—Genus *Williamsonia*, Carr.

There are three species of a fossil from Kukurbit, brought by Mr. W. T. Blanford, which I place in the genus *Williamsonia*, Carr., from the English Oolite (Linn. Transact., Vol. XXVI, p. 680. Phillip's Yorkshire, iii edit., 1875, p. 227, Pl. XXIV, f. 5), and which I will describe as *Williams. Blanfordi*, Fstm.

Of less importance is *Cycadolepis*, Sap., which occurs also near Bhoojooree in one specimen, and to which I give the specific name *Cycadol. pilosa*, Fstm.

II.—*Coniferæ.*

Among the remains of this class are again some very important species for the determination of age, as they in general are very characteristic of the strata in which they occur.

1.—Genus *Palissya.*

From three localities we have got coniferous branches, which I place without hesitation in this genus, because they have its peculiar characters.

a.—Palissya Bhojoorensis, Fstm. This species I think different by some marks from *Palissya Brauni*, Endl., and from that occurring in the Rajmahal series, *P. Oldhami*, Fstm.; so I name it as above. Locality: Bhoojooree; in reddish soft clay.

b.—Palissya sp. like that from the Rajmahal series, and also from the Jabalpur group, which is probably of the same horizon.

This specimen is from Thrombow, and I think perhaps this locality is lower in age than the others. This species signifies again that we should take for the Kach series a lower age than has lately been given to it. The other species of ferns and the other *coniferæ* suggest the separation of the Kach from the Rajmahal series.

Two other branchlets occur, which I would consider also as *Palissya*, Endl. They resemble very much Phillips' *Taxites laxus*, Phill., which, however, seems also to be a *Palissya:* and I would designate it as *Palissya laxa*, Phill., sp.

2.—GENUS, *Pachyphyllum* Bgt.

a.—Pachyphyllum divaricatum, Fstm.—A coniferous branch, agreeing quite with *Cryptomerites divaricatus*, Bunb., from Scarborough; but I believe this fossil more correctly placed in the genus *Pachyphyllum*, Schimp., as I have also placed our specimen.

Locality: Kukurbit.

3.—*Echinostrobus*, Schimp.

a.—Echinostrobus expansus, Schimp. The most frequent, and also quite characteristic coniferous plant, is a form with thin and dichotomous branches, having the general aspect of a *Thuya* or *Cupressus*, and which also at first was described as *Thuytes expansus*, Stbg. (Phillips). It is now placed by Schimper in his new genus *Echinostrobus*, Schimp. This species also is thus identical with a species from the English Oolite.

Locality: Kukurbit, frequent.

4.—*Scales* of fossil cones.

Very remarkable also are some rather frequent fossils, which on the first view must be recognized as scales of fossil cones. If we look after analogies in existing literature, we find some quite the same in Phillips' Geology of Yorkshire, and recently in Mr. Carruthers' paper on some undescribed coniferous fruits from secondary rocks of Britain (Geo. Mag., 1869). Phillips mentioned this fossil as "winged seed"; while Mr. Carruthers described them with *Araucarites* as scales of cones of this genus. Our fossils are of the same kind.

Locality: Pretty frequent at Kukurbit.

This may, therefore, be the general view of fossil plant remains from Kach:—Generally considered, the flora declares itself at once as Jurassic. The particular horizon must be determined by the most characteristic fossils. These are—*Oleandridium* (*Tæniopteris*) *vittatum*, Schimp. *Alethopteris Whitbyensis*, Gopp.; Gen. *Pachypteris*, Bgt.; *Otozamites* cf. *Goldiæi*, Bgt.; *Cycadites Kachensis*, Fstm. (*Palissya*, Endl.); *Pachyphyllum divaricatum*, Fstm.; *Echinostrobus expansus*, Schimp. *Scales*.

All these fossils occur in the English Oolite of Scarborough and Whitby: and the same plants from Jurassic strata in Kach may be placed generally in the same age. While some localities seem to indicate a lower horizon, we can say that the Jurassic strata of Kach generally are of an Oolitic age; and it is of a lower Oolitic horizon, corresponding to the strata seen on the Yorkshire coast at Scarborough and Whitby, with which our flora has about ten genera and species in common. With the Oolitic flora of Italy and France there are only some genera in common; as is also the case between those floras

and the English Oolitic flora. With the Rajmahal series, as we will see, the Kach beds have only about three or four species in common, while, moreover, there is a great difference in the most characteristic forms.

The localities here mentioned are (taking the supposed oldest first) :—

1.—Near Gooneri, with *Actinopteris* (Schenk)-like forms; gray sandy clay.

2.—Thrombow, with *Palissya*, like the same from the Rajmahal series and the Jabalpur group; in the same gray sandy clay.

These two indicate a lower age, and perhaps represent the Rajmahal series in Kach.

3.—Kukurbit, with most of the characteristic types: *Oleandridium*, *Otozamites*, *Cycadites*, *Palissya*, *Pachyphyllum*, *Echinostrobus* (*Thuytes*), fossil *scales*, all with oolitic species; in gray sandy clay.

4.—Bhoojooree, with *Pachypteris specifica;* in a reddish soft clay.

5.—Doodaee, with *Alethopteris Whitbyensis*, Göpp.; in a reddish-gray soft clay.

These three, it can scarcely be doubted, are of lower oolitic age.

6. Loharia, with *Otozamites imbricatus*, Fstm.; in a ferruginous sandstone.

All of these can be determined with more or less accuracy as lower Oolitic, excepting Loharia, which is not so distinct. But generally a lower oolitic age must be taken for them; only the two localities, Gooneri and Thrombow, indicate a lower horizon.

As I have already mentioned, there seems to be a "*palæontological contradiction*" between the evidence from the animal and from the plant remains. The latter occur in the upper groups of the local Jurassic series as described by Mr. Wynne, the marine fauna occurring in the lower groups. According to Dr. Waagen's researches on the *Ammonite* fauna, this is not older than Bathonian; and yet the plants, which are from a higher horizon, indicate generally an age as old as the Bathonian or Bath-oolite, and some of them a still older horizon.

Such are the palæontological facts regarding which we can only say that plants of lower oolitic age still flourished in this region after that animals of younger strata had been living in the adjoining sea. It would seem, moreover, from the fact that *Ptilophyllum*, Morr., and other species occur also in the Rajmahal series, that the flora of Kach, though generally oolitic, had an earlier existence in India than in the strata of England.

II.—Flora of the Rajmahal Series (in the Rajmahal Hills and Godaveri District).

The flora of the Rajmahal series in general, and especially that of these strata as typically seen in the Rajmahal hills, is more abundant than the Kach flora, both as regards the number of specimens as well as of genera and species. I will therefore first discuss shortly the flora as exhibited in this region, and having established the typical forms here, we can recognize them in other places.

The fossil plant-remains of the Rajmahal series in the Rajmahal hills have formed already the object of a valuable work begun by Mr. Oldham and Prof. Morris, but of

which only six fasciculi appeared, with 35 plates and 52 pages text.* The following is a systematic abstract of the collections up to date† :—

A. CRYPTOGAMÆ ACOTYLEDONES.

I.—*Equisetaceæ.*

Perhaps in all formations characteristic forms of this order occurred. We have from here *Equisetum*, called *Equisetum Rajmahalense*, Schimp, (Oldh., Morr. Pl. II, f. 2-3. Pl. XXXV, f. 3-4), which is near to some liassic and rhœtic forms. In Kach, as we saw, no *Equisetaceæ* were observed.

II.—*Filices.*

These are pretty frequent in the Rajmahal hills, with some most characteristic forms.

1.—Order *Sphenopteridæ.*

a.—Sphenopteris, Bgt.: by *Sphenopt. Hislopi*, Oldh. and Morr. Pl. XXXI; *Sphenopt. membranosa*, Fstm. and *Sphenopt. arguta*, L. and H.; Pl. XXXII (O. and M.); this is an Oolitic species in England.

b.—Dicksonia: by *Dicks. Bindrabunensis*, Fstm. Pl. XXXVII, f. 2-2a; this is a *Sphenopteris*-like fossil with a fructification by which it must be placed as *Dicksonia*.

c.—Hymenophyllites, Bgt., by *Hymenophyllites Bunburyanus*, Fstm. (*Sphenopt. Bunburyana*, Oldh. and Morr. Pl. XXXII f. 5-6.)

2.—Order *Neuropterides.*

a.—Cyclopteris, Bgt. On Plate XXXVI (Oldh. and Mor.) (not yet published) are drawn two fragments of a *Cyclopteris*-like leaf not well defined. Later I got two others, one of them quite distinct, with the characters of a *Cyclopteris*, which, therefore, may be called *Cyclopteris Oldhami*, Fstm., Pl. XXXVII, f. 5-6.

b.—Thinnfeldia, Ettgh. A very interesting genus already known by A. Braun (1840), but described as *Kirchneria* Br., and later by still other names. The systematical position is, following Mr. Schimper, with the *Neuropterideæ*, in which I must agree with him. The geological horizons for this genus are Lias and Rhœtic. We possess from Buskoghat a specimen of a plant which I took at once to be a *Thinnfeldia*; and this has been confirmed by the discovery of another well marked specimen near Burio, so that I will describe this plant as *Thinnfeldia indica*, Fstm. Pl. XXXIX f. 1-1a, Pl. XLVI f. 1-2-2a.

3.—Order *Pecopterides.*

There are some quite distinctive forms for the Rajmahal series, and also for the characters belonging to this family.

a.—Pecopteris gleichenoides, Oldh. and Morr., Pl. XXV, XXVI; placed by Schimper as *Gleichenites*, and called *Gl. Bindrabunensis*, Schimp.; is very frequent and typical for these strata. Schimper may be right. Mr. Oldham also placed this species as *Gleichenites*.

b.—Pecopteris (Alethopt.) indica, Oldh. and Morr., Pl. XXVII, is indeed an *Alethopteris* with the same specific name. It is allied to *Asplenites Rösserti*, Schenk, from the Rhœtic (Bavaria), and to some other species of *Alethopteris*; important. *Pecopt. salicifolia*, Morr., is also to be placed here.

* The figures which M.M. Oldham and Morris have already given in their work I will mark, "Oldh., Morr., Pl. , fig. "; those to be drawn in my continuation of that work are here marked as "Fstm., Pl. fig. ."

† Besides the plant remains I am going to describe, there are also fossil silicified woods pretty abundant, which, however, I am unable to mention here, as they want more examination. I will describe them later together with others of the same kind.

c.—*Pecopteris* (*Asplenites*) *macrocarpa*, Oldh. and Morr., Pl. XXVIII, is an *Asplenites* very near to *Asplenites Ottonis*, Schimp., also from the Rhœtic (Bavaria); important.

d.—*Pecopteris lobata*, Oldh. and Morr. Pl. XXIX, XXX, pretty frequent; it may retain this name; it seems an Indian type.

4.—Order *Tæniopterides*.

This family gives one of the chief characters of the Rajmahal series, especially in the Rajmahal hills; there are very frequent large and interesting forms which are very important for the determination of the age.

a.—*Macrotæniopteris* (*Tæniopteris*) *lata*, Schimp., (Oldh. and Morr.) Pl. I, II, IV, *Tæniopteris musæfolia* (Oldh.) Schimp., which are not really different, represent the character of this family, being very near to *Tæniopt.* (*Macrotæniopt.*) *gigantea*, Schimp., from the Rhœtic.

b.—*Tæniopt.* (*Angiopteridium*) *McClellandi*, Oldh. and Morr., Pl. VI, (*Tæniopt. spathulata*, McClell.), being near to *Angiopteridium* (*Tæniopt.*) *Münsteri*, Schimp., from the Rhœtic, these two fossils indicate a lower age for this series than that hitherto supposed.

c.—*Tæniopt. ovata*, Schimp., described as *Tæniopt. ovalis* (Oldh. and Morr.), but different, as I find by the denticulation of the margin. O. M. Pl. III; Fstm. Pl. XXXVII, f. 1.

d.—*Macrotæniopt. Morrisi*, Oldh., is also a separate species. O. M. Pl. III, IV.

e.—*Danaopsis Rajmahalensis*, Fstm. Pl. XXXVIII. 4. The essential characters of this very interesting genus are, I believe, exhibited in this species.

In the *Cryptogamæ* we may, therefore, note as important *Equisetum Rajmahalense*, Schimp., *Thinnfeldia indica*, Fstm., *Alethopteris indica*, Oldh. and Morr., *Alethopt. macrocarpa*, Oldh. and Morr., *Macrotæniopteris lata*, Oldh., and *Angiopteridium McClellandi*, Oldh. and Morr.

B.—PHANEROGAMÆ—COTYLEDONES.

1.—*Zamieæ*.

In this class we find another marked character of the Rajmahal series, by which again this flora differs quite distinctly from that of the Kach series.

a.—*Pterophyllum*, Bgt. The most developed genus, with a great variety of forms, of which the most characteristic are *Pterophyllum carterianum*, Oldh., *Pterophyll. Morrisianum*, Oldh., *Pterophyllum princeps*, Oldh. and Morr. (which is quite near to *Pteroph. Braunsi*, Schenk, from the Rhœtic), *Pterophyll. Rajmahalense*, Morr. &c., as they have been described and figured by Oldham and Morris. Pl. X, XVIII.

b.—*Ptilophyllum*, Morr. About this I have already said that I take this name instead of *Palæozamia*, Endl., observing it as an Indian type, and therefore as a distinct genus; this genus is known both in the Kach and the Rajmahal series; and also the same species occur in both; but while *Ptiloph. Cutchense*, Morr., prevails in Kach, *Ptiloph. acutifolium*, Morr., is the most abundant in the Rajmahal series. *Ptilophyll. rigidum*, Schimp., I take to be identical with this latter, and think *Ptilophyll.* (*Palæozamia*) *affine*, n. sp., not very far from *Ptilophyll. Cutchense*, Schimp. As varieties I distinguish here also *Ptiloph. acutifolium* var *maximum* and *Ptiloph. Cutchense* var *minimum*; this genus constitutes a connective form between these two rock-series, belonging to the same great geological epoch; it is Jurassic.

c.—Otozamites Braun. In this genus I put some species, which in the first description of the Rajmahal series by MM. Oldham and Morris were also described as *Palæozamia* Endl., O. M. Pl. XIX. Their *Otopteris*-like *habitus* is so distinct, especially in the disposition of their veins, that at first I thought it right to place them with *Otopteris*, Schenk. It seems best, however, following MM. de Zigno and Saporta, to abandon this old genus, and to take all *Otopteris* forms as *Otozamites*, because they have more characters of the *Zamieæ;* so these *Otopteris*-like fossils from the Rajmahal hills (which stood formerly as *Palæozamia*) must be put to *Otozamites*, Braun. The species are *Otozamites abbreviatus*, Fstm. (*Palæozamia bengalensis*, Oldh. and Morr.), *Otozamites bengalensis*, Schimp.; it is near *Palæozamia brevifolia*, Braun, or *Otopteris Bucklandi*, Schimp., but Mr. Schimper considers it different by its more obtuse leaflets, and names it as above.

d.—Zamites, Bgt. Of this genus, we have two specimens, pretty well preserved. I call the species *Zamites proximus*, Fstm., as it is very near to a living *Zamia*. Fstm. Pl. XLI. f. 1-2.

e.—Dictyozamites, Oldham. Quite a peculiar genus in general, and a marked Indian type; we only know it in the Rajmahal series. It was at first described and characterized as a *Dictyopteris*, Gutb., and as *Dictyopt. falcata*, Morr., and *Dictyopt. falcata*, var. *obtusifolia*, Morr., by Mr. Morris in the original description of Rajmahal plants in the Palæontologia Indica, 1862, Pl. XXIV. Although at first of the same view (Memoirs Geological Survey of India, II, p. 320), Mr. Oldham, in the description of the Rajmahal plants, p. 40, developed another and more correct opinion about this fossil, taking it as belonging to the *Cycadeaceæ* (*Zamieæ*) near *Otozamites*, Braun, and proposed a new generic name, *Dictyozamites*, with its diagnosis, which I fully adopt. I propose the specific name *Dictyozamites indicus*, Fstm., taking both varieties as the same. It was originally known only from *Amrapara*; lately I found it also near Murrero. Outside of the Rajmahal hills we know it also in some other places.

2. *Cycadeæ.*

a.—Cycadites, Brgt. The occurrence of true *Cycadeæ* is also of importance for the determination of age, because they indicate always a lower horizon in the Jurassic series. Fossils of this genus are very abundant in the Rajmahal series. MM. Oldham and Morris have described three species; but I believe there are only two, *Cycadites Rajmahalensis*, Oldh., and *Cycadites confertus*, Morr., putting the third, *Cycadites Blanfordianus*, Oldh., with this latter, O. M. Pl. VII, IX.

Some fruit-like fossils I recognize as belonging to the genus *Williamsonia*, Carr.; they are very similar to those in Phillips' Geology of Yorkshire, 3rd Ed., 1875, Pl. XXIV, f. 2, 3, 4, 5, from the lower sandstones (lower portion of lower Oolite) of Whitby.

Besides these, there are also some cycadeous stems and fructifications, which, however, need no further mention.

3. *Coniferæ.*

In this family we find some well marked forms, serving to indicate the age of the Rajmahal series, and also as characteristic of that formation.

1.—Genus *Palissya*, Endl.

Two species occur, one pretty frequently typical of the Rajmahal series.

Palissya Oldhami, Fstm., O. M. XXXIII, is a form like *Palissya Brauni*, Endl., from Rhœtic strata; it is the same form as mentioned already in the Kach series from Thrombow.

Another form I call *Palissya pectinea*, Fstm., Fstm. XLV. which is very frequent; it has lately been found also in other places, which I take to belong to the Rajmahal series. MM. Oldham and Morris have figured the first as *Toxodites indicus*, and the second as *Cunninghamites confertus*.

2. *Cheirolepis*, Schimp.

Some very tender-leaved branchlets, first described as *Araucarites gracilis*, n. sp., O. M. Pl. XXXIII, XXXV. and which have a *Lycopodites*-like aspect, must, I believe, be placed in this genus. I name them *Cheirolepis indica*, Fstm. I may at once mention that no *Lycopodites* is known higher than in the Permian; all *Lycopodites*-like plants in the newer strata being *coniferous* plants.

3. *Echinostrobus*, Schimp.

I have already said in the preceding note on the Kach flora, that some species of the genus *Thuytes*, Ung. (which have been sometimes also called *Arthrotaxites*, Ung. and others), have been shown by Prof. Schimper to be *Echinostrobus*, Schimp. In the Rajmahal series there occur some branches which must be so placed.

Echinostrobus Rajmahalensis, Fstm. O. M. Pl. XXXII. 8. Fstm. XLV.: I call by this name some branches resembling the now disused species, *Baliostichus ornatus*, Stbg., *Arthrotaxites Baliostichus*, Ung., and *Arthrotaxites Frischmanum*, Ung., but which three form, as I think, only one species. Our Rajmahal specimens are, however, a little different.

Such is the flora of the Rajmahal series in the original area, so far as now determined. I estimate the whole number of good species as about fifty. The description of the flora of this series, as the continuation and conclusion of the valuable work of MM. Oldham and Morris, illustrated by eleven additional plates, will, I hope, be published as soon as possible after the Flora of Kach, now in the press.

In taking a general view of the Flora of the Rajmahal series in the Rajmahal hills, we may point out the following plants as the most important forms:—

1*st*.—As characteristic of the formation:—

- *a*.—*Alethopteris indica*, Oldh. and Morr.
- *b*.—*Asplenites macrocarpus*, Oldh. and Morr.
- *c*.—*Gleichenites* (*Cyatheides*) *Bindrabunensis*, Schimp.
- *d*.—Some species of *Tæniopteris*, Bgt..
- *e*.—The frequent occurrence of the genus *Pterophyllum*, Bgt.
- *f*.—*Dictyozamites indicus*, Fstm.
- *g*.—*Palissya pectinea*, Fstm.

2*nd*.—For determination of the age:—

- *a*.—*Equisetum Rajmahalense*, Schimp.
- *b*.—*Alethopteris indica*, Oldh. and Morr.
- *c*.—*Asplenites macrocarpus*, Oldh. and Morr.
- *d*.—*Thinnfeldia indica*, Fstm.
- *e*.—*Macrotæniopteris lata*, Schimp.
- *f*.—*Angiopteridium Mcclellandi*, Schimp.
- *g*.—The frequent occurrence of *Pterophyllum*, especially *Pt. princeps*, Oldh.
- *h*.—*Otozamites brevifolius*, Br. (*Otoz. Bengalensis*, Schimp).
- *i*.—The true *Cycadites*, Bgt., and *Palissya Oldhami*, Fstm. (near *Palissya Brauni*, Endl.)

All the plants enumerated in this 2nd list are of such a facies that they indicate at once a lower zone of the Jurassic *period, and I have no hesitation in assigning to them a* Liassic *age.* At first, these plants were considered as oolitic. M. de Zigno, in a written consideration, which is in my hands, dated 1861, and later in a paper, Sopra i depositi di piante fossili dell' America settentrionalle, delle Inde e del Australia, etc, Padova, 1865 (of which there is a Report in Leonhard and Geinitz n. Jahrb. 1866, p. 381), regards them rather as Liassic. In the Vienna Jahrb, der Geolog. Reichsanst., 1861-62, Verhandl., p. 80, we find the Rajmahal fossils mentioned as agreeing with the Austrian Keuper plants. Mr. Ettingshausen, in his "Farrenkrauter der Jetztwelt," p. 22, remarks of *Tæniopt. lata* and *Taen. Morrisi* quite distinctly: "In formatione *Lias* dicta ad Bindrabun Bengaliæ." We may therefore adopt, as the result of our special study confirming the opinions of the several authors, that these Rajmahal strata are to be taken as Liassic.

Mr. Schimper, however, in Vol. III of his Paléontolog. végét., has put the greatest number of our Rajmahal fossils in the oolitic period; while one of the same, *Equisetum Rajmahalense*, Schimp., occurring in the same strata with the others, he puts as Rhœtic, which, of course, is contradictory. This is still more remarkable when we find Mr. Schimper placing also the *Glossopteris* and *Phyllotheca* of the Damuda series in the Oolitic period.

It remains now only to enumerate the localities of the fossil plants I have examined, or where they are said to occur. There are twelve localities known, in an alphabetical order, as below:—

1, Amrapura; 2, Bindrabun; 3, Burio; 4, Busko Ghat; 5, Ghutiari; 6, Jamkoondih; 7, Murero; 8, Muchwa Pass; 9, Onthea; 10, Salempoor; 11, Shahabad; 12, Sooroojbera.

The total number of species being taken as fifty, the number known from the several localities is as follows:—

1-5, 2-32, 3-9, 4-5, 5-2, 6-2, 7-4, 8-2, 9-4, 10-1, 11-1, 12-1.

The greatest proportion is in No. 2, Bindrabun, with thirty-two species; the next is No. 3, Burio, with nine.

Note on the age of the flora of some places in the Godavari District, especially of the sandstones of Kolapilli.

In the Records of the Geological Survey, 1871 and 1872, Mr. W. T. Blanford has published a paper in two parts on some plant-bearing sandstones of the Godavari valley, and descriptions of others in the same district (Records, Vol. IV, p. 107, Vol. V, p. 23, Vol. IV, p. 49)

All the places Mr. Blanford mentions, and from which he has got fossil plants, he has recognized as belonging to the Damuda series and to the Kamthi group (upper portion of Damudas in general) on account of the occurrence of *Glossopteris* and *Vertebraria* in the characteristic forms for those beds. This is indeed so; and our Museum contains several sets of fossil plants, from localities in the Godavari District (from the lower part of the river valley) which are at once to be recognized as plants of the Kamthi or Raniganj group.

But we have got also from another locality, Kolapilli, near Ellore, discovered by Mr. King, a set of plants which certainly belong to another group and another age.

The plants from this locality are preserved in a very fine sandstone of a yellow-brown colour (ferruginous). They are pretty numerous, but do not represent many species; sufficient, however, to determine the age of the flora. The following systematical enumeration will enable us to compare these fossils with others already described and determined.

I.—*Equisetaceæ.*

Wanting.

II.—*Filices.*

1.—***Alethopteris indica***, Oldh. and Morr.: some very characteristic specimens quite like the Rajmahal form, and also like ***Asplenites Rosserti***, Schenk.

2.—***Asplenites macrocarpus***, Oldh. and Morr.: frequent, very closely allied to ***Asplenites Ottonis***, Schimp.

3.—***Gleichenites Bindrabunensis***, Schimp., (***Pecopteris gleichenites***), Oldh. and Morr.: a fragmentary specimen.

4.—***Tæniopteris*** (***Angiopteridium***) ***spathulata***, McCl.: a fragment of a ***Tæniopteris***, agreeing well with fig. 7 on Pl. VI, Oldh. and Morr., Rajmahal Flora.

5.—***Tæniopteris*** (***Angiopteridium***) ***ensis***, Oldh. and Morr. Two specimens I believe belong to this species of the Rajmahal Hills.

III.—*Cycadeæ.*

1.—***Pterophyllum Morrisianum***, Oldh., one or two specimens, one pretty large.

2.—***Pterophyllum carterianum***, Oldh. A very frequent species.

3.—***Pterophyllum*** comp. distans, Morr. (***Hislopianum***, Oldh.) The specimen recalls also the ***Pteroph. Braunianum***, Göpp.

4.—***Ptilophyllum*** (***Palæozamia***) ***acutifolium***, Morr. The common form. Pretty frequent.

5.—***Ptilophyllum cutchense***, Morr. This species is also represented by some specimens.

6.—***Dictyozamites indicus***, Fstm., formerly ***Dictyopteris falcata***, Morr. Of this very interesting and curious fossil, the systematic position of which, however, has not yet been quite determined, but is provisionally taken as a *Cycadeæ* near *Otozamites* Braun, there occur some specimens near Kolapilli, but on account of the more sandy stone, the reticulation of the veins is not so distinct as in the same species from the Rajmahal hills or from near Madras. But the identity is proved.

7. A fruit of a cycadeous plant belonging to the genus ***Williamsonia***, Carr; it is pretty large, as in the Rajmahal series; in Kach we found some smaller specimens.

IV.—*Coniferæ.*

1.—***Palissya pectinea***, Fstm. This quite characteristic coniferous species occurs pretty frequently.

2.—***Palissya Oldhami*** also is represented in one specimen.

3.—***Echinostrobus*** sp. Two specimens, somewhat indistinct, but from the ramification and disposition of the leaves they can be placed only in this genus; the species I have not yet determined.

4.—Scales of *coniferous plants* of a very large size, belonging most probably to ***Araucarites***, occur in some specimens.

This general view of the plants from Kolapilli exhibits at once some of the most frequent and most characteristic species from the Rajmahal series in the Rajmahal hills, so that we may safely take them to be on the same horizon and age.

General table showing the relations of the now discussed series and their floras.

KACH (GENERALLY KACH SERIES) MIDDLE JURASS., EUROPE.		RAJMAHAL SERIES (LOWER JURASS., EUROPE).	
Upper horizon.	Lower horizon (?)	Rajmahal Hills.	Kolapilli.
Loharia; not quite distinct. *Doodaee, Bhoojooree, Kukurbit;* these 3 with Oolitic forms, as enumerated above. *Oolite* (lower).	*Thrombow* with a *Palissya, like that from* the *Rajmahal series* and *Narbada* valley ? *perhaps representing here the Rajmahal series. Near Gooneri,* containing the *Actinopteris*-like forms.	*Abundant* large *Tæniopteris, Pterophyllum; true Cycadites;* some *Otozamites, Palissya* (reminding ? *Brauni,* Endl.) etc., offering a *liassic* view of the plants. Some *Alethopteris,* and a constant *Palissya* etc., *Lias* (of Austria ?); *common plant with* the *upper* horizon of Kach, *Ptilophyllum,* Morr.; with *Thrombow* the *Palissya* species, called by me Pal. *Oldhami* Fstm.	Containing abundant *Pterophyllum,* besides all the characteristic plants for the "Rajmahal series" of the Rajmahal hills (which must be taken as typical). *Liassic. Common* with *Thrombow,* the *Palissya* species called by me *Pal. Oldhami.* Fstm. With the *upper horizon* the coniferous scales (but much larger).

There are two species of the genus *Ptilophyllum* Morr., common to both series; they are *Pt. cutchense* (prevailing in Kach) and *Pt. acutifolium,* Morr., prevailing in the Rajmahal series.

I would here give a list of the several works I have referred to bearing on our plant-bearing strata, their flora and age. We have Captain *Sherwill* (Journ. Asiat. Soc., 1851, p. 577,) on the Rajmahal hills, with a map.—Mr. *Th. Oldham* (in Journ. Asiat. Soc., Bengal, 1854, p. 263,) On the geology of the Rajmahal Hills.—*Th. Oldham* and *Morris,* "On the flora of Rajmahal series, Rajmahal hills," Palæont. Indica, 1862.—Mr. *Th. Oldham,* Mem. Geol. Survey of India, 1860, II Vol., "On the geolog. age of the rocks in Central India, Rajmahal hills, etc."—Captain *Grant,* "Geology of Kach." Transactions of the Geolog. Soc., Vol. I, sec. series, with description of the plants by Prof. Morris.—*Mc Clelland:* Report of the Geological Survey of India, 1848-49, with plates, Calcutta, 1850.—*W. T. Blanford,* Memoirs of the Geolog. Surv. of India, Vol. VI, "On the geology of a portion of Kach," p. 17.—Mr. *Wynne:* Mem., Geolog. Surv. of India, Vol. IX, "Geology of Kach".—Dr. *W. Waagen:* Records of the Geological Survey of India, "Abstracts of results of examination of the ammonite fauna of Kach," etc., Vol. IV, 1871, No. 4, p. 89.—Dr. *Waagen:* "Jurassic fauna of Kach," Palæontologia Indica, 1875.

De Zigno: Some observations on the flora of the Oolite: Quarterly Geolog. Journal, 1860, p. 110.—*De Zigno:* Sopra i deposite di piante fossili dell America settentrionule, *delle Inde* e dell Australia, etc., Padova, 1863.—*De Zigno:* Observations sur les Planches de l'Ouvrage de Mr. Oldham: "Sur les Plantes fossiles des Rajmahal hills" (manuscript, 1861, in our Library).—*De Zigno:* Flora fossilis formationis Oolithicae, Vol. I, 1856-68, pag. VI, etc.—*Bunbury:* General remarks and postcript in his Fossil plants of Nagpur: Quarterly Journal Geolog. Soc., XVII, (1861), p. 34, f. f.—*Hislop*: "Nagpur Sandstone" etc.: Quarterly Journal, Geolog. Soc. XVII, (1861), p. 349. Rajmahal Hills.—*W. Haidinger*: Verhandlungen der k. k. Geolog. Reichsanstalt, Wien: Pflanzenfossilien aus den Rajmahal Hügln, 1861-62, Bericht. vom, 31 Juli, p. 80.

I may also mention some works in which special mention is made of our fossils. There is Mr. Schenk's "Flora der Grenzschichten zwischen Keuper und Lias", 1867, where especially the systematical position of some of our Rajmahal species is discussed, and where *Equisetum Rajmahalense,* Oldh., is considered as a l i a s s i c form. Mr. *Ettingshausen,* in his "Die Farrenkräuter der Jetztwelt" 1865, mentions especially the *Tæniopteris lata,* Oldh., *Tæniopt.,* Morris, Oldh., placing it with the living *Acrostichum* (which, however, is of no use in the question of the age); as to the localities he states: "In formatione *Lias* dicta ad *Bindrabun* Bengaliæ."

Mr. *Saporta*, in his "Végétaux fossiles du Terrain jurassique," in the Paléontologie Française, 1872-1875 (Nos. 1-18), mentions in several places our fossil plants from the Rajmahal hills. Of Mr. *Schimper's* Paléontologie Végétale, 1867-1874, I have already said what was necessary, and repeat only that our Rajmahal fossils, and also those of the Damuda, must be eliminated from his list of the fossil plants of the Oolitic period, and be put in their proper places.

In 1875 we have again a note by Mr. *Zigno* on the Rajmahal Flora in Verhandl. d. k. k. geolog. Reichsanst. No. 17, where he again approves the Liassic age of the Rajmahal Flora.

I must finally mention a paper by Mr. *H. F. Blanford*, published in the Quarterly Journal, Geolog. Society, 1875, November, with the title, "On the age and correlations of the plant-bearing series of India, and the former existence of an Indo-Oceanic Continent", in which, however, regarding the flora all is repeated from the former publications of the Survey, and therefore requires the same corrections. I will only mention that all the lists of fossil plants given by Mr. Oldham were only provisional; and that many of the genera were subsequently determined to be different; which, of course, also changed the conclusions to be made from them.

It is thus obvious that I do not agree in identifying the horizon of the Kach with that of the Rajmahal series in the Rajmahal hills, on the Godavari and near Madras. Nor is it at all probable that the Damuda series are Permian; as the *Schizoneura*, which is so very frequent in the upper Damudas, is not known anywhere in Permian strata, but in Trias. I may also mention the recent discovery in the Barakar group of a *Voltzia* and of a very distinct single-pinnate *Neuropteris*, Bgt., which till now is nowhere known in the Palæozoic (*viz.*, Permian) strata, but only in the Triassic (*viz.*, Buntsandstein—grès bigarré) rocks*; proving, besides other evidence, that the lower Damudas also are of mesozoic age, as I will show more fully in a later paper. From these facts one will be also able to make further conclusions on the age of the Australian plants, as being identical with our Damuda plants.

DESCRIPTION OF A CRANIUM OF STEGODON GANESA, WITH NOTES ON THE SUB-GENUS AND ALLIED FORMS, *by* R. LYDEKKER, B. A. (CANTAB), *Geological Survey of India.*

The cranium described in the present paper is a remarkably fine and nearly perfect specimen belonging to *Stegodon ganesa* (Falconer). It was discovered by Mr. Theobald in the grey sandstone beds of Maili, belonging to the middle Siwalik series. In describing this specimen I have of necessity been led to examine the other allied species, and in the present paper intend giving a few notes on the sub-genus.

The sub-genus or genus (?) *Stegodon* as originally founded by the late Dr. Falconer, comprised four species, *viz.*, *S. insignis*, *S. bombifrons*, and *S. ganesa*, from the Siwaliks, and *S. cliftii*, from the tertiary beds of the Irawadi: subsequently, Professor Owen (Q. Jour., Geol. Soc., Lon., 1870, p. 417) added two other species to this list, *viz.*, *S. orientalis* and *S. sinensis*, founded on fragments of molar teeth brought from China. In spite of the reputation of the founder of these last two species, I cannot help doubting their validity as being based on the characters of the teeth alone, as these are so very similar in all the species; at the same time, I should be by no means surprised that, if at any time the crania of the Chinese species should be discovered, it (or they) would be found to differ from the Indian species.

* Schimper and Mougeot: Monographie des plantes fossiles du grès bigarré des Vosges, 1847, 40 plates.

The sub-genus was founded on the peculiar character of the molar teeth, the grinding surface of which is divided into a series of transverse hills and valleys, the enamel passing over the surfaces of both, and not penetrating into the substance of the crown: these ridges are capped by a number of small eminences, generally known as cusps; there is never any distinct antero-posterior valley running across the ridges, by which negative character the sub-genus is at once easily distinguished from the allied genus *Mastodon.*

Of the four Indian species of the sub-genus, *Stegodon cliftii* has the smallest number of ridges, which sufficiently distinguishes the molars of this species. Of the other three species we find the ridge-formula to be exactly the same in all; the molars, indeed, of *S. insignis* and *S. ganesa,* Dr. Falconer says, (Pal. Mem., vol. I, p. 80). are so alike, that the "differences are practically insufficient for the discrimination of the two species." The molars of *S. bombifrons* are distinguished from those of the other two species by having the ridges "broader and less elevated, with more open hollows;" the distinction is, however, very slight indeed. Prof. Owen, in his paper cited above, lays great stress on the number of cusps on the ridges, as affording a valuable distinction between the molars of the different species of *Stegodon*; this appears to me to be a somewhat insufficient character, and one which would be extremely likely to vary in different individuals, and I do not find that it holds good for the molars of the crania of the different species in the collections of the Imperial Museum.

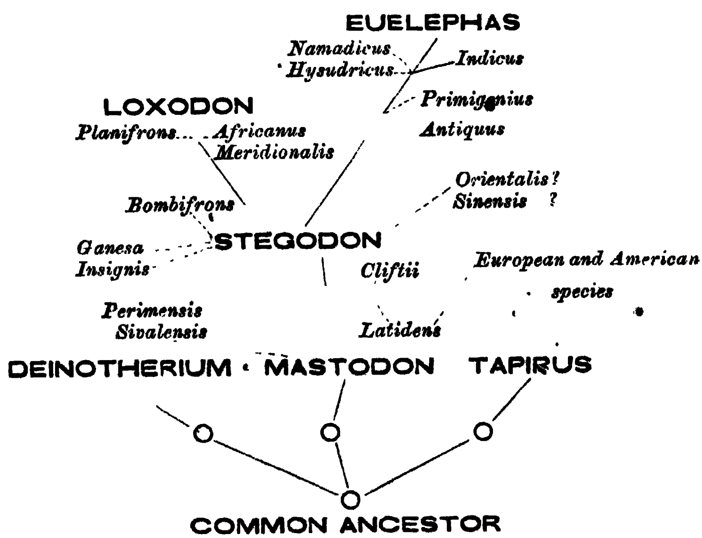
I therefore consider the molars of *Stegodon ganesa* and *Stegodon insignis* as indistinguishable one from the other; the skulls are, however, easily recognized, that of *S. insignis* "being singularly modified, so as to bear an analogy to the cranium of *Deinotherium,* while the head of *S. ganesa* does not differ much from the ordinary type of the elephant" (Pal. Mem., vol. I, p. 81). In spite, however, of this striking difference in the two crania, Dr. Falconer, subsequently to writing the above passage, had reason to doubt the specific distinctness of *S. ganesa*: he did not state, however, on what grounds, or with which species he proposed to amalgamate it; the distinctness, however, of the molars of *Stegodon bombifrons* shows that it must have been with *S. insignis.* If any certain distinction could be drawn between the molars of *S. insignis* and *S. ganesa,* it would be of itself sufficient to confirm the distinctness of the latter; as it is, we are driven to depend on the character of the crania alone.

At first sight the huge tusks and alveoli, the large size of the inter-alveolar fossa and of the nasal fossa, together with the high and vaulted frontals, appear alone quite sufficient to distinguish the cranium of *S. ganesa* from the small-tusked *S. insignis,* with the small nasal fossa, and the peculiar flattening and ridging of the frontals; if, however, we turn to the figures of the crania of *S. insignis* in the "Fauna Antiqua Sivalensis," we shall find that the peculiar shape of the frontals of the adult of *S. insignis* is not present in those of the young animal: (the peculiarity in the adult arising from a partial development of the intertabular fossæ). From this fact, in accordance with Falconer's doubts, I have thought it might be possible that *S. ganesa* is only a huge-tusked male form, of which *S. insignis* is the female; in the former, in correlation with the great development of the lower part of the skull to carry the large tusks, the frontal sinuses are also developed in like manner, and not aborted as in the female *(S. insignis).*

The size of the crania of *S. ganesa* in the British Museum is, however, much larger in proportion to those of *S. insignis* than occurs in the living species of elephants; and I cannot but think it expedient to continue to consider the two as distinct species, as the crania are so widely different. The present cranium has smaller tusks than any described specimen of *S. ganesa,* although they are still much larger than those of *S. insignis.* I think it, therefore, not improbable that this may be a female form, which supposition would

at once do away with the above hypothesis; there appears to be a difference in the number of cusps in the molars of this specimen from typical forms, which, according to Prof. Owen, might be grounds for specific distinction.

Apparently, from the specimens in Falconer's collections in the typical Siwalik strata of the districts adjoining the Jamna, which include the highest beds of the series, the skulls and molars of the highly specialized sub-genus *Euelephas,* as exemplified by *E. hysudricus,* were equally common with either of the species of *Stegodon;* passing, however, more to the westward, towards the Satlej and the Beas districts, we find that most of the fossils obtained by Mr. Theobald (which form the chief part of the Siwalik collection of the Geological Survey) are obtained either from the middle grey sandstones, or the lower red clays,—both older than the Markanda river beds; among these fossils the proportionate number of *Stegodon* molars to those of *Euelephas* is about 30 to 1; or in the proportion of 10 to 1 (allowing for the three species of *Stegodon*). In the newer deposits of the Narbada valley, we find *Euelephas Namadicus* the dominant species, while *Stegodon* is only represented by a few specimens of *S. insignis*; in the present Indian Fauna, *Euelephas* alone survives, *Stegodon* having died out; the latter genus is confined to the tertiary beds of India, Burma and China; we find, therefore, as might have been predicated on anatomical grounds, that the simple form, *Stegodon,* appears to have been gradually dying out since Siwalik times (how long before that it originated we are unable at present to say), and to have been replaced by the more highly specialized forms of *Loxodon* and *Euelephas,* of which the latter is the most highly specialized. The pedigree of the *Proboscidia* is probably something of this sort, as shown in the diagram; *Tapirus* connecting it with other *Ungulata.*



Until geological explorations have been carried out to a greater extent in the countries between India and England, it is impossible to say in which direction the migration of elephants took place; it would not, however, be unreasonable, from the number of species and genera found in the Siwaliks and other Indian strata, to suggest that India was the original home of the family (*Elephas, Mastodon, Deinotherium,* and *Tapirus* are all found fossil in India), and that the migration took place from thence, all the sub-genera having taken origin

in that country, probably long before Siwalik times; thus *Loxodon planifrons*, or an unknown allied species, might have travelled westward and given rise to *Loxodon meridionalis* of the English "Forest Beds," and subsequently to the living *Loxodon africanus*. In the same way, *Euelephas* may first have given rise to the Siwalik species, from which again sprung the Narbada species and the living *Euelephas indicus*, and on the other hand, to another branch which travelled over Asiatic Russia, and thence to Europe, producing the Mammoth *E. primigenius* and the other European species.

Mastodon, as having the widest distribution—Europe, Asia, and America—as well as from being the most generalized type of the family, may well be considered as the most ancient form of the group; its earliest occurrence in India is in the supra-nummulitic beds of Sind and Kach, and its latest existence was probably in the marshes of the Ohio, where it not unlikely lived down to the human period; it is the only American representative of the family, and its migration may well have taken place from India westward to America. *Mastodon* was the first of the elephants to die out in India, it being unknown after the Siwalik period.

The present specimen of *Stegodon ganesa* exhibits the whole of the cranium in very perfect and complete condition; the chief injuries are the absence of the zygomatic arches, which have been broken off close to their respective origins; and the absence of the greater portions of the tusks, the incisive sheaths having been broken off near their base; the bones composing the wall of the left temporal fossa have been much crushed and comminuted, but have been subsequently roughly recemented together by a calcareous infiltration.

In its original state the cranium was almost completely embedded in a mass of the common Siwalik grey sandstone, which, though generally soft, became almost as hard as granite as it approached the bone. The mass of stone in which the specimen was embedded was, as is so commonly the case with Siwalik fossils, a detached boulder, which had undergone a considerable amount of rolling and weathering: the fractured extremities of the tusks had evidently been exposed for a considerable time to the action of the weather, being much decomposed, and easily separating into a series of concentric rings. The bone had lost its animal matter, adhering very strongly to the tongue, and absorbing a great quantity of the glue with which it was treated.

The general outline of the facial and frontal portions of the cranium correspond nearly with that of Colonel Baker's large cranium of this species, in the British Museum; this is noticeable in the comparatively large size of the incisive sheaths, the large and deep fossa between them, and in the continuity of the fronto-incisive planes; when examined in detail, however, certain smaller points of difference exhibit themselves.

The frontal plane of Colonel Baker's specimen of this species is remarkable for its broad and smooth expanse, scarcely roughened by any ridge or protuberance; in this specimen a bold rounded ridge is continued upwards and backwards along the mesial line of the frontals from the nasals, and terminates in a rounded boss, some eight inches above the naso-frontal suture; on either side of this ridge there is a marked depression, broadest above the nasals, and gradually narrowing as it passes upwards: externally to this depression a sharp trihedral ridge is continued upwards from the post-orbital process of the frontal, imperceptibly losing itself in the flat surface of the parietals. There is no resemblance to the flattened upper frontals and supra-nasal ridge of the cranium of *Stegodon insignis*.

The large dimensions of the nasal bones (see table of measurements) differ from those of typical specimens of the species, and still more widely from those of all other species, especially *S. insignis*, in which they are remarkably small; they are more than double the size of the corresponding bones in Colonel Baker's cranium, and four times that of the nasals

of *S. insignis*. The nasals form a downward prolongation of the mesial frontal ridge; they are of great thickness, being composed of a mass of finely cancellated bony tissue, project far over the nasal fossa, and have a somewhat quadrate free termination. The lower border of the frontals, forming the upper boundary of the nasal fossa, sweeps upwards in a bold arch on either side of the nasals: in Colonel Baker's cranium this line of the frontals is much straighter and is scarcely interrupted by the small nasals. The lower border of the nasal fossa slopes away evenly from either side to the median line; at this line a deep triangular notch, on either side of which are the posterior processes of the premaxillæ, connects the nasal and incisive fossæ; below this notch the incisive fossa becomes suddenly very deep; in Colonel Baker's cranium the inter-premaxillary notch is much shallower, and the processes blunter: in *S. insignis* the notch is almost absent, and the incisive fossa becomes gradually, not suddenly, deep.

The incisive fossa is of great size and depth, its outer walls are nearly perpendicular to the base, and parallel to each other; in Colonel Baker's cranium the inner walls of the incisive sheaths are curved, the concavity looking inwards: in *S. insignis* the incisive sheaths are very slender and diverge rapidly outwards, in a manner very different from either of the above.

In a side view of the cranium, the upper boundary of the large temporal fossa is of an elongated ear-shape, just as in Colonel Baker's specimen; the cranial wall of this fossa runs in a plane nearly at right angles to the roof of the cranium, as far down as a line connecting the post-orbital process of the frontal with the lower border of the posterior zygomatic root; along the line of the nervous foramina, there is an abrupt fall inwards from this vertical plane, to join the plane of the molar alveolus. In Colonel Baker's specimen the wall of the temporal fossa begins to curve inwards very rapidly, which curve is continued without any break at the nervous foramina, to join the plane of the molar alveolus. In *Stegodon insignis* the temporal fossa is curved antero-posteriorly, as well as from above downwards, differing very markedly from either of the above forms.

The walls of the temporal fossa, in this and in all other specimens of *Stegodon ganesa* that I have seen, are straight antero-posteriorly, and are placed nearly at right angles to the plane of the face; there is never any wedge-shaped indentation of the fossa towards the median line in the middle of the frontals, which renders the greater part of the walls of the fossa visible from the front of the skull, as always occurs in the crania of *Stegodon insignis*, and which gives it its characteristic form.

In the crania of all other elephants that I have seen, the course of the optic nerve, after emerging from its foramen, is continued outwards across the orbit, in a deep channel, which grooves the inferior surface of the post-orbital process of the frontal; in the present specimen this channel is absent, the surface of the bone being perfectly smooth; this feature is probably only an individual variety.

In a front view of the cranium, as stated above, only a very small portion of the temporal fossa of either side comes into the field of view; the external outline of the lower portion of the cranium differs in several respects from Colonel Baker's specimen, probably owing to the smaller size of the tusks. The anterior zygomatic root stands out from the outer border of the incisive sheath almost at a right angle, throwing the infra-orbital foramen entirely out of the line of the incisive fossa, while the foramen itself looks nearly directly forwards. In Colonel Baker's specimen the anterior zygomatic root slopes away very gradually from the outer wall of the incisive sheath at an obtuse angle of nearly 120°, the infra-orbital foramen occupies a notch in the outer border of the incisive sheath, and looks considerably outwards as well as forwards. The position and form of the anterior zygomatic root and foramen in the present specimen resemble the position of the corresponding

portions in the cranium of *Stegodon insignis*, and might, therefore, be taken as evidence for the specific identity of the two forms: I rather regard this position, however, as due only to the smaller size of the tusks; while the greater size of the present cranium, and the form of the frontals and temporal fossæ, serve to show that a smaller tusked form of *Stegodon ganesa* exists, without making any approach in the form of the upper cranium to the cranium of *Stegodon insignis*, so peculiarly modified in the upper regions.

The occipital surface is much flattened, having an irregular hexagonal outline, of which the parietals form the longer superior border, and the condyles the shorter inferior border; on its outer side, this surface slopes away rapidly to form the posterior boundary of the temporal fossa; the hollow for the insertion of the ligamentum nuchæ commences about five inches above the foramen magnum, and is continued vertically upwards for a distance of eleven inches, averaging an inch and a half in width, and rather less in depth.

The following measurements of this cranium are compared below with those of Colonel Baker's specimen, figured in plate XXI of the Fauna Antiqua Sivalensis, and described at page 33 of the description of the plates to the above:—

Measurement in inches of crania.	Present specimen.	Col. Baker's *S. ganesa*.
Width of incisives at infra-orbital foramen	6·5	7·5
Width of ditto below ditto	6·5	10·75
Length of cranium from occipital condyles to anterior border of molar alveolus	25·0	25·0
Vertical height from condyles to sinciput	25·0	24·0
Lateral diameter across occipital condyles	9·0	9·2
Antero-posterior diameter of left condyle	5·0	5·0
Transverse diameter of ditto	4·0	3·85
Ditto ditto of foramen magnum	3·0	3·0
Antero-posterior diameter ditto	2 9	3·1
Diameter of widest part of supra-occipital	28·0	29·2
Ditto naso- præmaxillary fossa	16·0	16·0
Interval between nasal fossa and post-orbital margin of frontal	4·3	4·55
Extreme width of frontals	27·5	26·25
Length of incisive (broken in specimen)	21·0	31·0
Depth of zygomatic fossa	4·5	4·25
Estimated width of cranium between centre of temporal fossa	17·0	19·25
Height from lower margin of meatus auditorius externus to sinciput ...	20·0	18·0
Ditto posterior margin of molar alveolus to sinciput	30·0	32·0
Length from upper border of foramen magnum to posterior margin of molar alveolus	9·0	9·5
Vertical height of orbit	8·9	3·78
Transverse diameter of middle of left incisive sheath	8·0	11·5
Vertical diameter of left incisive sheath	7·8	10·6
Ditto of infra-orbital foramen	3·7	3·85
Transverse ditto ditto	1·5	......
Interval between distal ends of second molar	4·0	2·7
Interval between proximal ditto ditto	5·2	3·25
Length of right second molar	16·0	11·9
Width of ditto ditto ditto at second ridge	4·3	4·05
Ditto ditto ditto ditto at penultimate ditto	5·5	5·0
Vertical height from posterior extremity of outer border of second molar alveolus to post-orbital process of frontal	21·5	21·0
Distance between outer surfaces of second molars at fifth ridge	13·5	12·6
Antero-posterior diameter of meatus auditorius externus	1·2	1·15
Transverse ditto ditto ditto	1·0	1·0
Length from upper border of foramen magnum to tip of nasals	55·0	......
From tip of nasals to præmaxillary protuberance	7·0	......
Height from lower border of anterior zygomatic root to crown-surface of second molar	25·0	......
Width of nasals at base	5·5	3·0
Length of ditto	3·8	1·6
Long diameter of posterior nares	6·0	......
Transverse ditto ditto	3·0	......

From the above table of measurements we find the general measurements of the two crania not varying more than might be expected in two different individuals; but the respective dimensions of the tusks and their alveoli are very different. Thus it will be seen that, in the present specimen, the transverse diameter of the incisive sheath above and below the infra-orbital foramen is the same; while in Colonel Baker's cranium the sheaths are constricted at the foramen, and suddenly expand below this point. The transverse diameters of the incisive sheaths of the two crania below the infra-orbital foramina are in the proportion of 8 to 11·5, and the antero-posterior diameters in the proportion of 7 to 10. The circumferences of the respective incisive sheaths are 20 and 30 inches; the length of the tusks of Colonel Baker's specimen, from the distal extremity of the incisive sheath to their tip, is 9 feet 8 inches; if the length of the tusks in the present specimen bears the same proportion to their diameter, as it does in Colonel Baker's specimen, this would not have exceeded 6 feet 9 inches, making a difference of 2 feet 9 inches in the length of the tusks in the two individuals; very probably the difference may have been still greater.

The next most noticeable difference in the measurements of the two skulls occurs in the palate; the palate of the present specimen is wider than that of Colonel Baker's specimen, in the proportion of 4 to 2·7 at one end and 5·2 to 3·2 at the other. The nasals of the present specimen are nearly twice as large as those of Colonel Baker's specimen; the transverse measurements being 5·5 and 3·0, and the antero-posterior measurements 3·8 and 1·6 inches.

The vertical height of the present specimen is one inch greater than that of Colonel Baker's specimen; and the width of the frontals is 1¼ inch greater.

If now we turn to the figures of the crania of *Stegodon insignis* given in plates 16 and 17 of the "Fauna Antiqua Sivalensis" with their accompanying measurements, we find that the specimen figured in plate 17, fig. 1, has a diameter of only 25·5 inches across the occiput, 3 inches less than in the present specimen; while its vertical height is 4·5 inches less; the whole cranium, in fact, being greatly smaller than the present, and differing by the peculiar form of the forehead so greatly as to have very little general resemblance.

From the above facts I conclude that the present specimen proves the existence of a small-tusked variety of *Stegodon ganesa*, of which the cranium is at least as large as in the big-tusked variety, and which, moreover, shows no approach to the peculiarly modified cranium of *Stegodon insignis*, of which the tusks are still smaller; the present specimen might well be a female of *Stegodon ganesa*, while *Stegodon insignis* will still stand as a distinct, though closely-allied, smaller species (in the modern acceptation of the term) distinguished by its peculiar frontals and temporal fossæ; the teeth of the two species being indistinguishable from each, and indicating a very close affinity.

Continuing our description of the present specimen, we find that two pairs of molars are protruded from their alveoli; the first pair have been in wear for a considerable period, and are much worn away in front, the number of ridges remaining being only seven. In the second molar of the left side, eight ridges may be counted, together with an anterior talon ridge: between the first and second ridge there is a small conical tubercle on the outer side. This molar is only partially protruded from its alveolus; from the width of the last visible ridge, there must be two or three more ridges still concealed in the alveolus: this would make the tooth the last of the permanent molar series, in which the number of ridges should be either ten or eleven; the penultimate molar never has more than eight ridges; the fact of this tooth being the last of the series proves the animal to have been fully adult, and that the tusks had attained their full size and development.

The unworn ridges on the last molar are remarkably clear and sharp, displaying in great perfection the cusps on their summits; as in the typical specimen, they have the usual transverse bowed form, with clean transverse valleys, without any trace of a median, fore-and-aft cleft; the outer side of the worn ridges is lower than the inner side.

The first ridge of the ultimate molar is unusually thick and massive; it has an imperfectly-divided talon on its anterior side: its longer or transverse diameter is 4 inches, and the shorter or antero-posterior diameter 2 inches; the interval between the summits of the second and third ridges is 1·2 inches, and that between the seventh and eighth ridges 1·6 inches. The depth of the valley between the sixth and seventh ridges is 1·5 inches; transverse diameter of the fifth ridge is 4·2 inches. On the fifth ridge there are no less than thirteen sharply-pointed cusps visible: the sixth cusp, counting from the inner side, on this, and the immediately adjacent ridges is somewhat larger than the rest, and its hollow on the outer side somewhat deeper. This sixth cusp and valley will probably indicate the line homologous with the medial fissure of the molars of *Mastodon.*

The great number of cusps on the ridges of the last molar is an unusual character among the Siwalik *Stegodons*; a character to which, however, as stated above, I do not attach much value: the thirteen cusps on the fifth ridge do not probably represent the total number, as the whole of the ridge is not protruded from its alveolus; there are, no doubt, at least two still concealed; this would bring up the whole number to fifteen.

The greatest number of cusps contained in a single ridge of any of the molars of *Stegodon ganesa* figured in the "Fauna Antiqua Sivalensis" is eight; in *S. insignis* ten; and in *S. bombifrons* nine. In *Stegodon orientalis*, Prof. Owen says, the cusps are "about a dozen in number"; and in *S. sinensis* he infers them to be twelve or thirteen. If the number of cusps be any criterion of specific identity, as Prof. Owen thinks it is, the present cranium would belong to a fifth Siwalik species, which would be most nearly related to the Chinese species. The close resemblance of the cranium, however, to the typical *Stegodon ganesa* at once forbids this supposition; and I should be therefore inclined to doubt the validity of Prof. Owen's new species, founded mainly on this character.

As an instance of the variability of this character, I may cite a specimen of a right mandible of *S. insignis* in the collection of the Imperial Museum (No. 63 S.); the specimen contains the third milk-molar just protruded from its alveolus; this tooth shows seven ridges; the fifth of these carries eleven cusps, a greater number than I have seen on even a last molar of this species. I think, therefore, that this character, as of specific value, must be abandoned; if so, Prof. Owen's Chinese specimens must also be abandoned, as they are founded chiefly on this character and some slight variation in the enamel.

NOTE UPON THE SUB-HIMALAYAN SERIES IN THE JAMU (JUMMOO) HILLS, BY H. B. MEDLICOTT, M. A., *Geological Survey of India.*

The 'Jamu Hills' may conveniently be taken to designate the several ranges, of steadily decreasing elevation, between the flanks of the Pir Panjál and the plains of the Panjáb, from the Rávi to the Jhelam. At the Rávi they are the direct continuation of the ranges in the Kángra district. For many years this ground has been a missing link in our study of the great Sub-Himalayan series of tertiary rocks. So long as those territories could boast of a geologist of their own, we refrained from trespassing upon his rights; but soon after the departure of Mr. Drew, steps were taken towards closing this gap in our wor . Every facility has been granted to us by His Highness the Maharajah and his ministers.

The special point to be cleared up was, the discrepancy between the sections of these rocks as described by me in 1862 (Mem. Geol. Surv., Ind., Vol. III) in the region of the Ganges and the Satlej, and those observed by Mr. Wynne in the country west of the Jhelam. I had made out two very marked breaks in the series. One was where the topmost beds of the great mammaliferous deposits rested against and upon an inner belt of older rocks. As the former were conspicuously the home of the famous Siwalik fossils, I restricted this name to that younger group of rocks, giving the name of Náhan to the older beds upon which they rested unconformably. It was certainly rash of me thus to tamper with a well-known name. Although the fauna of the Náhan rocks is still unknown to us, it presumably will include mammalian remains, having more or less of affinity to those known as Siwalik; and it may be palæontologically desirable to make the same name cover all. This, of course, can still be done, if required, substituting some local name in the application I gave to Siwalik.

The second break in the eastern section occurs where the Náhan rocks abut against the old slaty rocks of the higher mountains, high upon which there rests an extensive remnant of still older tertiary deposits, including at their base the nummulitic beds of Subáthu, transitionally overlaid by red clays and grey sandstones in distinguishable zones, to which I gave the names Dagshai and Kasáoli. I subsequently denoted these three older bands collectively as the Sirmúr group, it being desirable to restrict the name Subáthu to the nummulitic zone proper. There was little direct evidence as to how far the boundary between the Náhan and Sirmúr groups might also be an aboriginal unconformity, or altogether due to flexure and faulting; but the fact that in the lowest outcrops of the Náhan band over a very large area no symptom could be detected of the very characteristic Subáthu zone, nor any specific representative of the Kasáoli beds, which in the contiguous area are repeatedly marked by peculiar plant layers, gave strong presumptive evidence for the supposition of aboriginal unconformity.

No trace of these very marked stratigraphical features of the Simla region could be detected by Mr. Wynne in the country west of the Jhelam; although several of the zones could be identified with great certainty. The Subáthu nummulitics are very characteristically represented west of Mari (Murree), and over them, at Mari itself, the rocks exactly resemble the Dagshai beds; while at the upper end of the series the Siwaliks are in great force, with their characteristic fossils.

As an unknown quantity between these two contrasting sections there was the remarkable fact that the axes of flexure in the rocks west of the Jhelam have a direction at right angles to that of the contiguous Himalayan ranges; the change taking place abruptly along the course of the river. It is the junction or confluence, the knee, as it has been termed, between the lines of the Himalaya proper and those of the Hindú Kush. There seemed a possibility that the total disappearance westward of the boundaries so strongly marked at the base of the Himalaya east of the Satlej might be closely connected with this striking transverse feature of the mountain structure. Such, however, is not the case. These two systems of flexure are continuous and cotemporaneous.

The difficulty of establishing divisions in the immense series of tertiary strata which has so hampered Mr. Wynne in his examination of the trans-Jhelam country, had already strongly declared itself to me in the hills between the Satlej and the Rávi. On the map published with my memoir, it will be seen that the Náhan-Siwalik boundary and the Náhan zone itself is stopped abruptly and arbitrarily at the Satlej. I found that the abutting, overlapping junction of topmost Siwaliks against low Náhans had gradually changed into vertical parallelism; the ridge of Náhan rocks here taking the form of an anticlinal, sinking to the north-west, round the point of which the Siwaliks turn over into the inner valley. Finding that the several broad dúns (flat longitudinal valleys) of the Kángra district were occupied by rocks of Siwalik type, and not having time to work out their approximate separation from the core of Náhan beds in some of the dividing ridges, I coloured the

whole area as Siwalik, giving due notice of this on the map itself and in the descriptive text. Thus already in the Kángra district the Náhan-Siwalik boundary was extremely difficult to fix.

The other great boundary-feature of the Simla region, that between the Náhan and Sirmúr groups, also undergoes much change immediately west of the Satlej; and in a similar manner to that described for the Náhan zone; the whole Sirmúr group becomes lowered along the strike to the north-west, so that the Subáthu zone is altogether suppressed. On this account, and because this structure would probably bring in higher beds, the north-western extension of the Sirmúr band was coloured as Náhan in my map of 1862. It is for this zone the beginning of the compromise that must be adopted to reconcile the different distribution of the strata in the separate sections of the mountain region. The actual boundary of this innermost tertiary zone is still as clear as ever, because there is a corresponding change in the outer contact rocks; Siwalik conglomerates abutting against it all along the Kángra Dun.

There is still a leading feature of contrast between the two regions separated by the Jamu hills. In the Simla region the Subáthu beds rest on a deeply denuded surface of the next oldest strata, supposed to be of lower secondary age; whereas beyond the Jhelam no such unconformity has been observed. This, it is evident, is a difference of precisely the same character as those already noticed within the tertiary series; and it is very noteworthy that these changes coincide in position with the most remarkable bend in contour of the boundary of the higher mountains, formed of old rocks, where for a length of nearly eighty miles it runs north and south, making an angle of 45° with the general course of the range. The direct continuity of the outermost base of the hills bounding the plains is maintained, past this bend of the higher mountains, by a greatly increased width of the fringing belt of the tertiary rocks.

These leading features of the two regions, as partially sketched in the preceding paragraphs, have been for some time more or less fixed; and the interpretation I have put upon them is simply that the disturbances marking the Himalayan system, *as displayed in the centre of its area*, are of earlier date than those affecting the terminal portion and the Hindú Kush; that in early or middle secondary times a general elevation occurred of the south Himalayan area, along the border of which the Sirmúr deposits subsequently took place; that the eocene period was closed by the more special disturbance with crushing which constituted, perhaps, the principal phase of the mountain formation; that after a period of denudation the Náhan deposits set in; that a similar interruption produced the break between the Náhan and Siwalik groups; while during all that time little or no elevation took place in the region of the Jhelam. Our observations in the Jamu hills have not disturbed these conjectures.

During the past cold season I had the advantage of going over part of my old ground, from the Satlej to the Rávi, through the Jamu country, and over a part of the trans-Jhelam districts, in company with Mr. Theobald and Mr. Lydekher. The snow prevented us following the innermost tertiary boundary along the flanks of the Pír west of the Chenáb; but this was not our principal object, and Mr. Lydekher is now engaged in examining that ground. We satisfied ourselves that on the Satlej there is no assignable break, faulted or otherwise, in the sequence from the Náhan to the Siwalik strata, although a very approximate position (that given in my map) can be made out for the change from the harder, deeper-coloured clays and sandstones of the former, to the paler or brighter and softer rocks of the fossiliferous upper group. This distinction is more or less discernible throughout the whole range to the north-west. It may be very well seen on both sides of the Bakrála ridge between Jhelam and Ráwalpindi.

As might be expected from its much greater magnitude, the middle tertiary break—that appearing in the Cis-Satlej region as a Náhan-Sirmúr contact, and in the Kángra district

marked on my map as a Siwalik-Náhan boundary—is clearly defined for a much greater distance westward than the Náhan-Siwalik break of the Simla region. On the Rávi, as all through the Kángra district, the Siwalik conglomerates are in great force along it; but west of the river an oblique strike brings in lower beds, which are less distinguishable; still, the feature as a structural break is easily followed to near Udampúr, where the fault dies out in the irregular flexures of the region of the Choti-Táwi. Here one must trust to aboriginal characters of the strata in any attempt to separate the lower as well as the upper zones of tertiary rocks.

In examining the extension of the inner belt of tertiaries this year, I hit upon two outcrops bearing on this point. Where this zone runs north and south along the left bank of the Rávi, under the point of the Dháoladhár ridge, it is very much compressed, being not more than a quarter to half a mile in width. In this very crushed, probably inverted, outcrop I found a characteristic sample of the Kasáoli plant bed, the only occurrence of it known west of the Satlej. Should the unconformity between the Kasáoli and Náhan horizons in the eastern region be confirmed, this observation will extend the separation of the zones up to the Rávi; and I shall have been over-cautious in introducing the Náhan strata in this position so far to the eastward on my map.

Where the Rávi leaves its mountain gorge and turns sharply to the south, there is also an acute bend in the strike of the bottom tertiary zone, and from here to the westward this band increases steadily in width, chiefly owing to the gradual retreat of its inner boundary, which crosses the high ridge into the Chenáb valley north of Chinéni. The breadth here at fifty miles from the Rávi is over twelve miles. In the valley of the Pine over the village of Marún, fifteen miles from the Rávi, I got a small outcrop of earthy nummulitic limestone, the first identification of the Subáthu zone west of the Beas. This case illustrates well the difficulty of fixing the bottom division of the tertiary series—the Subáthu-Dagshai boundary, if the Sirmúr group maintains its distinctness so far; or the Subáthu-Náhan boundary, if the Upper Sirmúr group merges into the Náhan group, as seems certainly to occur at some part between the Rávi and the Jhelam. This nummulitic outcrop on the Pine, in the midst of a great section of bright red clays and pale-greenish sandy beds near the south boundary of the Sirmúr band, is about the highest position in which I have found nummulitics; and it exhibits again how closely the great supra-nummulitic red deposits are connected with that formation in the Himalayan region.

I may here note an important observation I made this year regarding the inner boundary of this oldest tertiary zone. In the position already noticed along the west base of the Dháoladhár where the recognisable band of these rocks is so narrow, being compressed, crushed, and apparently inverted, there is no definable boundary between them and the contiguous rocks of the mountain which here consist of a broken amorphous mass in a semi-metamorphic trappoid condition, red and green vesicular and quasi-amygdaloidal pseudo-trap being the prevailing type. The amygdala are not the smooth vesicles produced by elastic fluids in a fused rock; they are of irregular shape, but are quite filled with infiltrated minerals. There is a magnificent fan of the débris of this crumbling mass just below Simliu, and now deeply cut into on the left bank of the Rávi. I could not but conclude that this peculiar rock is a metamorphosed condition, through enormous pressure, of the Subáthu nummulitics. Now it exactly resembles the so-called trap of the Pír Panjál and Káshmír, the débris of which is the most abundant shingle in the torrents from that range, and of the age or origin of which there is no definite knowledge. If the observation here recorded can be extended to that region, an important step will be made towards understanding its intricate geology.

As the inner tertiary zone expands to the west of the Rávi, the enormous thickness of the supra-nummulitic groups has room to display itself. The cross-gorge of the Choti-Táwi is a line of depression, the rocks of the high ridge to the north-west of it having a steady south-easterly dip. Strata much higher in the series occur here. There are thick masses of

pale soft clays north of Chinéni that may even be Siwalik. Indeed, here for the first time in this zone, which in the east, as has been said, is lifted bodily upon a pedestal of the old slates, we find, as is so general in the outer tertiary zones, conglomerates along the inner boundary of the area and forming the top of the series. At several places in the upper Táwi valley, below the Bindi gap, coarse and massive conglomerates are at the contact nearly vertical. These are most important, as bearing upon the question of sub-division of this Sub-Himalayan tertiary series : do these beds represent the Siwalik conglomerates? If not, we can scarcely avoid the inference that there are concealed unconformities to be looked for. The search for fossils is the most hopeful way of settling the point; but as I was traversing the country by forced marches to pick up the leading structural features of a large area, I could not stop for this purpose. The internal evidence of the beds themselves is, however, very significant: the imperfectly rounded shingle, some blocks as large as 2 feet in diameter, is almost exclusively made up of the bottom tertiary sandstone. The identification is certain. A fact of this nature was one of the confirmatory points for the Náhan-Siwalik unconformity in the Simla region, the source of these boulders being there evident; whereas for the conglomerates on the Táwi there is no apparent source; every trace, so far as is known, of the tertiary rocks having been removed from the region to the north. The fact is, however, absolute as to their once having extended in that direction, and as to their disturbance and denudation before the deposition of this conglomerate, certainly suggesting possible unconformity here, and in favour of the conjecture, that these beds at the inner border of the tertiary area, and well in among the high ranges, may represent the Siwalik conglomerates.

One of the most interesting observations we made this season was the demarcation of a great inlier of old limestone within the tertiary area. The extreme north-west end of this feature at Dandli close to the Púnch river was noticed in my Memoir of 1862 (loc. cit., p. 89), and I have now to apologise for having given a mistaken reading of it, which has led to some confusion. I was sent up there in 1859 to report on an outcrop of coal at Dandli. I had only one day on the ground; and, fresh from the Simla region, I was too hasty in applying its features to this remote section. I at once recognised the Subáthu group at Dandli, crushed up at the south base of a great ridge of old limestone. Throughout the Simla region there is no carbonaceous band in the Subáthu group; but, owing to deep unconformity and crushing, this group is very frequently brought into contact with infra-Krol carbonaceous shales. The superficial similarity of these sections, in parallel geographical positions, led me astray. The coal of Dandli belongs to the nummulitic formation; and the limestone is not presumably Krol.

The first appearance of this inlier is eighty miles to south-east from Dandli, some seven miles north-west of Udampúr. It is not continuous throughout this distance, as there is no sign of it in the valley of the Bari-Táwi between Náoshera and Rájáori; but all the outcrops occur along the same line of flexure and upheaval. It is noteworthy that this line is on the general extension of the middle tertiary break of the Simla region, the outer boundary of the Sirmúr zone. The principal mass of limestone is at the south-east end, where for a length of thirty miles it forms a lofty picturesque ridge, through the very centre of which the Chenáb has cut a precipitous gorge, just north of Riássi.

The structure of this feature throughout conforms to that which is so dominant over the whole South Himalayan region, a normal anticlinal flexure, broken and faulted on its steep outer face. Besides this familiar transverse structure, the clearly defined outcrop of these groups betrays a regular longitudinal waving of the stratification. The interrupted outcrop with intervening younger rocks suggests this; and the detail shows it more clearly. At each end of these ridges the beds curve continuously round the point of the anticlinal as it becomes depressed. The river courses seem to have little fixed relation to this feature, the two Táwis cross on lines of depression; the Chenáb cuts through the middle of the Riassi ridge; the Púnch cuts the point of the Dandli ridge; and several minor streams seem specially to affect clefts or chasms across these steep ribs of hard limestone.

The relation of the Subáthu group to these limestone masses is most uniform; not only is there complete parallelism of stratification, but the beds in contact seem to be the same throughout. This is most markedly the case in the nummulitic group, the bottom bed everywhere being the peculiar pisolitic clay, identical with that I described as a bottom bed of the group at Subáthu (loc. cit., p. 78), and also identical with that in the same position on Mount Tilla at the east end of the Salt Range. It is normally a ferruginous layer, but the removal of the iron often leaves it nearly pure white. The coaly band with some shaly clays immediately overlies it; to which succeeds the limestone. Immediately under the Subáthu bottom bed there is very commonly found a sort of silicious breccia. The perfect angularity of all the fragments forbids the idea of their having undergone any transport, as would *primâ facie* be suggested by the occurrence of such a band over a very large area, and often when the bedding has undergone no contortion. In this rock iron-ore has been extensively mined at many places, especially on the Sangar-Marg ridge. I believe the rock to be a shattered condition of a sandstone band that often occurs at the top of the great limestone series. The ore is a cellular limonite occurring in nests and strings through the breccia; it is probably derived by decomposition and infiltration from the coaly band of the Subáthu group.

The great limestone itself is a dense cryptocrystalline rock, in this respect contrasting strongly with the compact and often earthy nummulitic limestone close above it. It is often thin-bedded, locally cherty, and occasionally has intercalated bands of silicious slates and flags. The aggregate thickness of the formation must be great. We could nowhere find any trace of fossils in it, and I could see no special points of resemblance in it to the Krol group of the outer Himalaya east of the Satlej. On the more gentle northern slope of the range the Subáthu group stretches high up along every spur; and the pisolitic bottom bed with its attendant quartz breccia occurs on the highest summits. It will be seen how this relation of the nummulitic zone here to the underlying formations agrees with that in the trans-Jhelam country, and contrasts with its total unconformity in the Himalayan region east of the Satlej.

At Kotli on the Púnch we have the feature representing the middle tertiary break of the Simla region, being the outer boundary of the inner tertiary belt. It is here a double folded-flexure, with inversion between the axes, and faulting along the inner (anticlinal) axis. On the strike to the north-west towards the Jhelam the compressed flexure expands, the faulting dies out gradually, and upper beds stretch across the anticlinal axis. We were not able to follow this line up to the Jhelam, but these changes in it are the same as occur in all these features as they approach the Jhelam; the faulting which is so common along the main flexures in the Sub-Himalayan region dies out; and in many cases the flexures themselves cease and are taken up, on the new strike west of the Jhelam, by representative, not continuous, features. The two main north-west south-east anticlinal flexures outside the Kotli dún seem to bend continuously into the north-east south-west anticlinals on either side of Mount Nar, west of the Jhelam. I had not time to follow them so far; but I got a very near view from the summits east of the river. The synclinal of the Sensar dún, between those anticlinal ridges, certainly rises with a steep south-east dip in the ridges flanking Mount Nar on the south-east and well seen at the Owen ferry.

The less defined flexures of the lower Jamu hills are also traceable into connection with the trans-Jhelam lines. The anticlinal crossing the Púnch to north-west at Suru bends round and runs into a branch of the Bakrála north-east flexure below Dangli ferry on the Jhelam. The main representative of the Bakrála anticlinal continues on to Sálgráon, where it merges into several minor transverse corrugations. Similarly, the broad north-north-east anticlinal of Lehri and Godári sinks into the synclinal area of Chaomúk; and further south, the Rhotás north-north-east anticlinal spreads and sinks into the synclinal outside the last branch of the Himalayan flexures, north-east of Bhimbar. On the whole, the transverse line of the Jhelam

would seem to be one of comparative depression; although, of course, the deepest section visible, the lower zones of rock are not so exposed along it as on parallel sections to the south-east. The river itself observes no rule in its windings amongst the points of these opposing flexures.

I could detect nothing definite in these mutually accommodating structural features to prove that either system is younger or older than the other. They fit into each other in a way that could only be effected by a simultaneous growth. The continuity of strike observable in each could not obtain if the strata had previously been affected by undulations of the other. Of the two, however, the strikes are much more steady in the north-west south-east system; a fact which may, perhaps, suggest that they had somewhat the start in their alignment. The great Bakrála flexure is almost serpentine in its windings. The form also of the north-east south-west flexures is less regular; and in its variation betrays the dominance of the Himalayan thrust: while to the south-west, the steep side of these flexures is almost uniformly on the south-east; to the north-east the steeper side is to the north-west. It is so in the Lehri anticlinal, and in the Bakrála flexure north of the Kasi.

In following the tertiary zones south-westwards from the Himalayan border to the Salt Range, some important changes are very marked. As is usual in the proximity of all the great Himalayan rivers, the Siwalik conglomerates attain an enormous special development near the Jhelam. They are finely exposed in the hills west of Sálgráon, where it is well seen how this character is due partly to encroachment upon the lower zone. When not in force, the conglomerates are confined to the topmost earthy-brown portion of the series; this band is largely represented here; but below it the grey sandstone is strongly conglomeratic for a thickness of several hundred feet. These coarse deposits decrease greatly to the south, and become confined to the topmost beds, as described by Mr. Wynne in the Kharián or Pabbi hills, south-east of Jhelam (Rec. Geol. Surv., Ind., Vol. VIII, p. 48).

The main fossiliferous zone of the Siwaliks continues in great force to the south. The uncertainty of our measurements of them does not admit as yet of any close comparison in this respect. Mr. Theobald has again during this season made a good collection from these beds, principally in the area immediately north of the Salt Range, between the Tilla and Bakrála ridges. Mr. Lydekher, when he returns from the field, will no doubt give a good account of them.

In the lower zone we again find a very marked contrast from north to south along the Jhelam, between the Sub-Himalayan region and the Salt Range. We have seen all along the former ground that the Subáthu-Dagshai boundary is the most unsettled of any in the Sub-Himalayan tertiary series; stray thin layers of nummulitic limestone being locally found high up in the purple clays transitionally overlying the distinctive Subáthu zone. In the Salt Range, on the contrary, this is the most marked boundary of any; thick, softish sandstones and clays rest abruptly on the clear nummulitic limestone. The commonest junction-layer being a conglomerate made up of water-worn pebbles of the limestone and its flints, I described the contact in my Memoir of 1862 (p. 91), as one of denudation. I do not think the term a misleading one for such a junction, although Mr. Wynne very properly insists upon the constant parallelism of the stratification in the two groups, and upon his failure to find even a single case of actual erosion in the lower group filled in by the upper one. It is quite evident, however, that a very considerable break in the tertiary series occurs at this horizon in the Salt Range, amounting, I should think, to several hundred feet of the Subáthu and immediately supra-Subáthu zones of the Himalayan sections.

An important formation not yet mentioned came largely under our notice in the Sub-Himalayan hills—high-level river-shingle capping the ridges and spurs of upturned tertiary strata and packed against their flank at fully 400 to 500 feet over the actual river courses, which must have been eroded to at least that depth since the period of these deposits. There is evidence also to show that to some extent at least this was a re-excavation of the channels out

of these deposits, *i. e.*, that the existing rock-gorges had been to a great extent cut out before their accumulation, then filled by them, and subsequently cleared out again. Bubhór stands on a great bank of these beds packed against a ridge of vertical Siwalik conglomerates; and the bottom beds are seen to pass continuously for some way up the gorge of the Satlej, while the top beds of the same set are found capping the inner ridge of grey sandstone above Naili. They are unquestionably of very ancient post-tertiary date.

The distribution of this formation in the hills is generally limited to a greater or less distance from the great river courses; a fact which seems simply a question of levels; the flat watershed of the dúns being commonly 500 to 600 feet over the main drainage level.

The supposed glacial deposits of the Kángra valley would belong to this old diluvial period. I must mention that though we were unable to account for the distribution of the great erratics otherwise than by glacial action, Mr. Leydekher and myself were unable to find the moraines so graphically described by Mr. Theobald (Vol. VII, p. 86). The features so named are, I believe, only ridges of erosion out of a deposit that must once have filled the whole valley, remnants of it being found on the outer ridge high over Kángra fort.

The same deposits are largely displayed about the Jhelam, capping the Rhotás ridge on both sides of the Kahán; and on the Potwár, filling the valley of the Soháu, and covering the country for some distance from the Bakrála and Tilla ridges with large blocks of stone, for the transport of which it is difficult to account. Mr. Theobald strongly advocates their glacial origin, finding what he considers evidence of an ice-stream from the south-east flank of Tilla, past the villages of Hunúla and Húrí, to within about 1,000 feet of the sea level.

As the principal object of our season's work, it is necessary to say something of the correlation of these tertiary groups, especially since, in the absence of direct information, conjectural affiliations have been published by the Survey—by Mr. Wynne in his Memoir on the Kohat Salt Region (Mem., Vol. XI, 1875), and by Mr. Blanford in his paper on the Geology of Sind (Rec. Vol IX, 1876). The former finds representatives of all the lower tertiary zones in the Kohat and Salt Range sections, and almost excludes the Siwaliks (see table, p. 24); while the latter runs the Siwaliks and Náhans together as equivalent to his Manchar (pliocene) group (p. 21). It is but right to explain that these opposite mistakes are largely due to some unpublished work of Mr. Theobald's in 1873-74, who, starting from the Satlej, somewhat arbitrarily restricted the Siwalik group to the outermost range of hills, and mapped all the rest as Náhans, up to the trans-Jhelam country, although finding in them fossils of the Fauna Sivalensis, the object set before him being to work out the presumed distinction of the Náhan and Siwalik faunas. Mr. Wynne accepted his stratigraphical identifications, and Mr. Blanford on his side was equally right in insisting that there was a very close affinity between the fossils said to be from the two distinct horizons.

Whatever value may be ultimately assigned to the unconformity which originally suggested the separation of the Náhan group in the Cis-Satlej region, the distinction of the zone as a comparatively barren formation at the base of the great mammaliferous Siwalik deposits will hold good, even if the fossils, whenever discovered, should make it desirable to designate the group as lower Siwalik. It has now been traced with fair certainty into the trans-Jhelam country, where it is represented by several hundred feet of sandstones and clays immediately overlying the nummulitic limestone on the east end of the Salt Range. It may not unlikely be the equivalent of Mr. Blanford's Gáj (miocene) marine group in Sind.

It seems very doubtful whether it will be practicable or desirable to separate this band from possible representatives of the upper Sirmúr strata, in the vastly greater thickness of purple sandstones and clays transitionally overlying the Subáthu group in the Himalayan

region proper, to the north of the Salt Range. We may be well satisfied if we can make out there an assignable boundary for the top of the Subáthu group. This remains to be done.

A word is necessary on the Subáthu group itself: at Subáthu, where it was first brought to notice through the collections of Major Vicary, described by D'Archiac and Haime, and all along the Himalaya up to Mari, the formation is principally made up of brown, olive, and red clays, with subordinate earthy limestone; the base of the group being very sharply defined throughout by very characteristic beds resting upon much older rocks. In my Memoir of 1862, owing to the mistake already noticed regarding the coal of Dandli, and other causes, such as the specific difference of the fossils as noted in D'Archiac and Haime's work, I remarked upon the want of agreement between the Subáthu group and the nummulitic band of the Salt Range. From the continuous observations of this season I was greatly struck by the remarkable correspondence between the thin nummulitic band at the east end of the Salt Range and the very base of the Subáthu group. The point is important with reference to the great change that takes place in the formation to the westward, both in the northern and southern region—the immense and rapid increase of limestone. From Mr. Wynne's description of the Mari ground, it would appear as if the "Subáthu group" overlay his "Hill nummulitic limestone;" but I am disposed to think, and information sent me by Mr. Lydekher strengthens the notion, that this great limestone takes the place of the upper Subáthu deposits. The coaly band, common to both regions, continues at the base of the formation all through the Salt Range and beyond it to the west. Thus it appears possible that the Subáthu group of the Himalayan region may contain representatives of Mr. Blanford's Nari and Kirthar groups, and even of his Ranikot beds, in Sind.

Our observations of this season have strongly brought before us the necessity of indicating an upper division in the Siwalik group of my Memoir of 1862, to represent the great conglomeratic zone and its equivalents at the top of the formation. We found repeated confirmation of my remark that the distribution of these Siwalik conglomerates is coincident with the proximity of the Great Himalayan rivers, they being generally represented elsewhere by brown clays undistinguishable from recent alluvium, or, if conglomeratic in this position, the pebbles are of local débris, not the hard torrent-shingle of the great conglomerates. There is no better example of this than at the Satlej, where there are some 4,000 feet of deposits highly conglomeratic throughout and very coarse in the upper portion. All are vertical, the strike being most easily followed continuously; and thus, within seven miles of the Satlej, in the parallel section above Basóli (Madanpur), we find only about 500 feet of conglomerate in the middle of over 3,000 feet of brown sandy clays. It was in these beds that Mr. Theobald found remains of *Bubalus* and *Camelus;* and Mr. Lydekher insists upon their separation from the main Siwalik deposits on palæontological grounds, suggesting that they may be the same as the Narbada fossil-beds. Upon this question of identification I think further consideration is needed. If the old alluvium of the Gangetic plains, which Falconer identified with the Narbada bone beds, are the equivalents of these vertical upper Siwalik strata, where in the plains are we to look for the representatives of the very ancient high-level terrace deposits already described along the base of the Himalaya as post-tertiary? I am inclined to think that these may rather be grouped with the old valley-gravels of the Peninsula. The gap between them and the top Siwaliks must be very great.

(An outline-map for this paper will be given in a later number).

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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1878. [August.

NOTE ON THE PROGRESS OF THE GOLD INDUSTRY IN WYNAD, NILGIRI DISTRICT, MADRAS PRESIDENCY, *by* W. KING, B.A., *Deputy Superintendent, Geological Survey of India.*

The official boundaries of Wynád having of late been altered by the annexation of its south-eastern frontier, or the country around Dayvallah, to the Commissionership of the Nilgiris, it becomes necessary, as in the heading of this paper, to refer to the present area of the gold industry as being in the Nilgiri district, instead of as hitherto in that of Malabar.

It is now nearly three years since my first notice[1] was written on the gold-fields of Wynád, at which time a commencement was about to be made by the pioneer Alpha Gold Company in working them. Since then two other Companies, the 'Wynád Prospecting' and the 'Prince of Wales' Tribute,' have made essays with the same intention; but none of these have, until very lately, succeeded in obtaining from the quartz an average percentage of gold at all equalling that of my preliminary crushings, namely, 7 dwts. to the ton. It is only within the last few months that some stone from 'Wrights' level' in the Alpha works has yielded from 11 to 17 pennyweights.

The returns obtained were all so much below the amount expected, that I was, at various times, applied to by those interested in the successful working of these Companies for any suggestions as to improved manipulation, or better mining; and in July last I made a hurried inspection of the works and the machinery.

In all cases, the mining had only been carried on near the surface; and in most instances disappointing results had driven the Managers and working Directors from one point to another of the reefs, as more or less promising stone seemed to present itself to the search. The Alpha Company was at a standstill through exhaustion of funds and breaking down of machinery; the Wynád Prospecting Company had nearly run through its capital, but hoped to be able to hold on by obtaining gold sufficient to pay working expenses; and the Prince of Wales' Company, which has no machinery of its own, had leased that of the Alpha Company,

[1] Records Geol. Surv. of India, Vol. VIII, Part 2.

and was collecting stone in readiness for crushing as soon as this machinery should be again in order.

Through the kindness of the Managing Directors, I have been supplied with the tables and statistics given in this paper; and these will show what the results have been up to date. They do not, however, show how and whence the stone was obtained, or the style of machinery used; I therefore enter into some detail in this paper regarding these two points.

The main results of the gold workings up to date are, as nearly as can be made out—for no correct returns were kept at first—that the gross amount of gold obtained by the three Companies up to the 14th of March 1878 is 271 oz. 9 dwts. 14 grains: the average yield of gold per ton of quartz on all this amount has been 4·5 dwts.; and this gold has been sold at prices varying from Rs. 40 to Rs. 45 the ounce. This low average yield is calculated on the whole absolute tonnage of quartz extracted in Wynád; but it is only fair to give the following averages for each Company's working:—

Alpha Company ...	...	769·5 tons	gives	2·27 dwts.
Wynád Prospecting Company	...	99·85 „	„	3·02 „
Prince of Wales' Company	...	322 66 „	„	10·5 „

Regarding the 'touch' of the gold, I have only two quotations from the Wynád Prospecting Company, namely:—"It varies much in quality, running from $5\frac{1}{2}$ to 9; Mr. Orr values the worst at Rs 36 per ounce." Mr. Orr, whose firm of jewellers in Madras has purchased most of the Wynád gold, writes me:—"The gold is of good quality, better than *sooga* gold,[1] for which we have paid Rs. 45 per ounce."

The country around Dayvallah is much broken up into low grassy hills and ridges, varying in height up to 300 feet, on the summits and crests of which the quartz reefs generally occur, and the valleys between these all lead into the great 2,000 feet deep Carcoor cherrum, or valley, of the Western Gháts, or into the smaller cherrums to the west of Dayvallah. The mines of the original workers, or the Korumber excavations, and even those of the latest European explorers, have all been run into the slopes of these small hills, or into the sides of the great cherrum; but very few of these have been driven at the lowest levels, or from the beds of the streams between the hills. Indeed, I doubt whether any workings have been excavated below the levels of these streams, except perhaps in the sides of the Carcoor valley; and there is no known instance of shafts having been sunk to the depth of the permanently water-holding country-rock, below that zone of variable thickness into which atmospheric influences are supposed to extend.

It is not here intended, after the popular cry, to imply that mining ought to have been carried to any extraordinary depths, such as the 7 or 800 feet levels of Australia, where working was in most cases only rendered necessary by the lodes having been worked out to these depths; nor is it an ascertained rule that richness

[1] Among native goldsmiths, there are ordinarily three qualities of gold, of which "sooga" is the medium

of veins almost always increases with the depth; but it is almost certain that displacement and non-continuity of reefs must be expected in so much of the country-rock as is exposed to atmospheric influences, and these defects would of themselves be sufficient to prevent steady and successful mining being carried on to any great extent at all near the surface. Local displacement can of course, as a general rule, only have taken place near the surface; but as this surface in Wynád is a very uneven one, such breaks must be expected in most of the ridges and knolls of the Dayvallah country, and to a much greater extent on the great slopes of the Ghâts. There is even a case in point in the Prince of Wales' Company's claim, where, on the east side of the ridge north of the Alpha works, a tunnel was driven with the expectation of cutting the northern course of the Skull reef on the prevalent eastward dip, but without success. It was then conjectured, from an outcrop of quartz on the south slope of this ridge, that the reef dipped quite in the opposite direction or westward, and a new tunnel was proposed.[1] The reef shows very well on the top of the ridge, lying at a very low angle to the eastward, but it has a tendency to resume the higher normal dip (25° to 30°) lower down the slope. From all I could see, the very low dip on the summit of the hill appeared to be due to a sinking down of the reef on the weathered and denuded foot-wall, while the abnormal lie of the outcrops of quartz on the lower slopes is most likely attributable to local displacement of the country-rock, very large and old slides of decomposed gneiss being not at all unfrequent in this part of the country.

It has been found that the reefs continue to the deep so far as workings have been carried out; but as these are of little depth, the country itself can only be looked to for evidence of any value on this point. Certainly many of the reefs can, on the upland, be seen to run deeper than the Skull reef; while outcrops are known to exist far down in the deep Ghát valleys, which to all appearance are the continuations of reefs on the upland; and it seems hardly probable that reefs which are traceable for miles in their strike can be so very limited in depth. There must, no doubt, be cases of thinning out, and it may be so in the case in question to some extent; but the evidence is against this, for some part of the reef (slipped or *in situ*) has been struck in the last attempt to reach it; though, even if it had not been struck, there would have been no clear proof of its entire absence, considering that the tunnel has such a small section, and that reefs are often capricious within small ranges. But it is a most common experience in this part of Wynád to find the reef outcrops much tumbled and slipped at various points among the ridges in the upland; and seeing that here, well up the sides of the hill in question, there are large outcrops of quartz in untoward

[1] This was at the time of my visit in August last; but it appears that no further attempt was then made to strike the reef, all efforts having been directed to the raising of stone from another more accessible part of the Skull reef. In the last report of this Company it is stated that another endeavour was made at the Prince of Wales' reef so late as the 1st of January 1878; but that as the old workings had completely fallen in, it was necessary to begin a fresh tunnel, and that the reef was only struck ten days before their lease expired. The length of the tunnel is given as 132 feet from entrance and about 50 feet in depth from surface; but there are no further details as to direction or position.

positions, one showing a westerly dip, I am the more inclined to view the case as one of displacement, in preference to one of sudden absence of the reef altogether over any appreciable area.

A further source of disappointment in the present system of mining may also, I think, lie in a possible mechanical distribution of some of the gold irregularly throughout the reefs by the mere percolation of water in this zone of varied decompositions; and that thus the gold may be found not only more fitfully distributed than is at times usual with the precious metal, but even to some extent washed out of the reef. Although there is no certain evidence that gold may be thus distributed through reefs, the possibility of such a mechanical process seems quite conceivable when the conditions of some of the reefs and their gold are considered in conjunction with the effects of such an exceptionally moist climate as that of Wynád, where the movement of water underground must be proportional to that on the surface. The quartz of many reefs, as far as is disclosed by the old excavations, and later by recent workings, particularly in the Skull reef, is much fissured and very often minutely, and even in part continuously, cavernous, or, again, quite crumbling and rotten from having been so largely charged with sulphides, while the gold left is generally in a minute state of division; and throughout this style of vein-stone there is tolerably free percolation of water in quite sufficient force to carry off minute gold. In nearly all the old excavations which I examined, and some of these are at the base of the Dayvallah ridges, water was dripping freely from the exposed surfaces of quartz. Nearly all the long outcrops of the reefs are really just catch-surfaces for water; while the reefs themselves and their clayey selvages must be, in many instances, only so many channels for the flow of water through the zone of decomposed rock. Among other modes of occurrence, the gold is found in empty cavities, once also occupied in part by sulphides, which have left their impressions on the quartz; or it is intimately associated with sulphides in partially filled cavities; or, again, it and the sulphides fill up such hollows. In the first and second cases, more or less sulphides have been removed, more generally by solution, but still to some extent mechanically; most likely as fine ochre. The gold associated with these was then either left behind, as is often the case, or it might, if minute enough, have been carried along with the solutions, or subsequently, by the ever-recurring passage of water, to be caught again in favourable hollows, or collected in and against the clayey casing,[1] or gravitated to the plane of constant saturation, or finally, carried out altogether by springs in the Gháts.[2]

With the possibility, then, of such a secondary distribution of part of the gold, and an extreme probability of encountering more or less disturbance of the reefs, in the ground within the reach of atmospheric influences, it becomes an important question how far those influences may extend beneath the surface, or, in

[1] The frequent richness of casing and wall-rock, though generally accounted for by chemical action, may be in part also due to this, as it were, secondary process of distribution; for there is free gold here as well as in the veins.

[2] For some interesting remarks upon the possible removal of gold by solution, see Raymond's Statistics West of the Rocky Mountains (1871), p. 506.

other words, at what depth the plane of constant saturation may be supposed to lie. It may, at all events, be concluded from the old excavations in the country-rock, debris of which is still frequently found at their mouths, and from the lately driven tunnels, which were mostly in tough clay (decomposed felspathic gneiss), that varied decompositions penetrate throughout a great portion of the upland country to the level of lowest drainage, that is, occasionally for 300 feet; and on this it is reasonably inferrible that weathering extends nearly as deep again in the neighbourhood of the main upland streams, and far inward horizontally on or near the edges of the Ghát slopes. Thus, arguing from the depth to which these influences extend on the upland, I should be inclined to look for the plane of constant saturation at 200 feet below, and 600 feet inwards from, the level of the edges of the Gháts. Further inland, the vertical depth might be taken at 100 feet.

At the same time it is, as has been shown by the late success of the Prince of Wales' Company, always possible that rich finds may be met with, the theory of fitful secondary distribution even meeting this view within the zone of variable decompositions; but these will be at the best but of importance in small adventures, such as those which have up to the present time been carried on in Wynád.

The Alpha Company opened up a large quartz 'boil,' or massed assemblage of veins, called the Skull reef, not far from the site of their machinery, the stone having been collected partly from the surface, and partly from fresh excavations in the old mines of the Korumbers. An adit was run, without any careful consideration as to direction, into the west side of the hill, with the hope that the reef might be cut somewhere about the lowest level of the old Korumber workings; but this was abandoned after a time. This excavation showed, at any rate, that driving will not be a very expensive item in the gold industry, as the rock is very largely weathered into a soft, more or less felspathic, clay, with occasional masses of undecomposed rock; but timbering is absolutely necessary to guard against the very frequent slipping of this clay. Then, as there had always been a desire on the part of the Manager (Mr. Withers) to drive at the southern outcrop on the steep slope of the Ghát, a tunnel was run in for a short distance at 'Wrights' level,' though still at a considerable height above the limit of permanent saturation, and well within the range of atmospheric influences. It is, however, from the same Wrights' level that the rich stone worked by the Prince of Wales' Company was subsequently obtained.

The want of success in the operations of the Alpha Company may be attributed, I think in great part, to the following causes. First, bad selection of stone. That there is very good stone in the reefs of the Alpha concession is proved by the later crushings of the Prince of Wales' Company. Second, unsystematic working of the reef or reefs, as exemplified in the fitful manner of taking stone from open quarries at the surface and from the different drifts, according as fancy led the authorities. Certainly better returns than those obtained might have resulted from one steadily-pursued tunnel and side galleries; while they could not have been worse than those got on the desultory plan of working.

Third, the proper amount of stone was never either mined or crushed in the time estimated for a paying result. The engine was overestimated in its power, and the 15 stamps were never worked at once; while the calculation was that, with 15 stamps, 15 tons of quartz could be crushed in the day's work. As it is, according to the returns supplied to me by the Alpha Company, I find that had their work been at the rate originally proposed, even under their small general average, the working of the mine would not have been a failure. The cost of raising and crushing 769½ tons of quartz was Rs. 2,971-0-5; and taking the value of their gold at Rs. 45 per oz., which is about what was paid for it, the amount realised on 91 oz. 12 dwts. 23 grains, or about Rs. 4,224-0-0, leaves a value of Rs. 1,252-11-0 for other expenses, besides raising and crushing. It is true that parts of eight months were occupied in this crushing, but the work ought all to have been done in two months and a half, reckoning 20 working days to the month; and had the work been properly done, it is almost certain that the cost of raising and crushing would not have been so high as it is set down in their table, the average cost of raising and crushing the quartz being Rs. 3·86 per ton, a far too high rate for Wynád mining.

The next adventure is that of the Wynád Prospecting Company, which has been carried on in a very small way with the intention of making preliminary trials as to the paying capabilities of the reefs. The works are situated on the edge of the Carcoor cherrum, near the outfall of one of the minor streams of the Dayvallah country, so as to take advantage of the water-power, while the reefs worked are also close by. In the case of this undertaking also, the mining has not been systematic, nor has it been carried to any depth in the hillside or downward. Of the reefs taken up by this Company, the Monarch was tried by a shaft and level drift run into the eastern side of the hill through which the reef runs, but was given up at 55 feet, as the lode was not struck, as had been expected, if the dip of the reef had remained constant. Operations were then confined to the Hamlin, Bear, Korumber and Etacull reefs, where they crop out on the edge of the Dayvallah plateau, or at the top of the northern slope of the Carcoor cherrum, and where there is an extraordinary number of old shafts and excavations of the old gold-diggers. It was from among the leaders of these reefs, in the soft decomposed felspathic gneiss, that lumps of quartz with visible gold associated with nests of limonite were obtained.

The Prince of Wales' Tribute Company was started on a very small scale, perhaps more with the idea of keeping the gold industry before the public. The mines, machinery, &c., of the Alpha Company were taken on a tribute for a certain period, and operations were commenced with stone from the old quarries of the Alpha works. A commencement was also made on the northern extension of the Skull reef in a high hill between the works and Dayvallah village, but the excavations were stopped owing, as already stated, to the reef not being struck at the expected distance, though the search was afterwards resumed, and the reef found just before the lease had expired. However, a persistent drive at Wrights' level resulted in a find of rich stone, which continued to give good results, until March last, when the operations were discontinued

The capital of the three Companies has thus been expended on what must be considered mere scratchings below grass, from which of course it was always possible that local rich finds might have been secured; as it is, no rich shoot of gold was struck until very lately, or until the capital and patience of the pioneer explorers was to all appearance worn out. It is evident however, from the latest reports of the working of the Prince of Wales' Company, that a rich vein has at length been struck, which may in its continued development fulfil all the promise of this new gold field.

At the Alpha works, there is a stamping apparatus of 15 stamps, arranged in three batteries of the ordinary kind used in Australia, whence this one was also procured. The batteries are driven by a 15 (nominal) horse-power locomobile, the fuel for which is obtainable in the forests close by. It is worthy of notice that this engine has never worked up to the power stated, various reasons being given for this, as that it was a secondhand English engine sent from Australia, or that the fuel was damp, both of which reasons are presumably fair. There is no doubt of the deterioration of fuel, there being no sheds for its storage, as should be the case in a climate like that of Wynád. However, I am firmly convinced that such a costly item as fuel, even in Wynád, should never be included in a scheme for working the gold when there is water-power sufficient for the purpose.

From the batteries, the crushed material is passed over copper[1] tables, mercury troughs, and blanket tables, after which the tailings are treated in a pulveriser. It was found, however, that complete extraction was not effected in the pulveriser, or, as it might more properly be called, amalgamating pulveriser, for much float-gold and gold associated with sulphides, which ought to have been taken up by the mercury, passed away with the slime. A reverberatory furnace was then constructed, in which the tailings were roasted and again pulverised, with somewhat better results; though even after this a perceptible amount of gold could always be shown by washing, and secured by hand-rubbing with sodium-amalgam. It was at the same time found, and experience in the other workings has since verified this, that sodium-amalgam should be used as much as possible, instead of simple mercury, in the extraction of Wynád gold. In the pulveriser, the tailings are made to pass between the grinding wheels and the bevelled edge of the circular pan in which they revolve, while the mercury lies at the bottom of this edge, just below the grinding surfaces; and thus the slime and sand are only ground finer, and then brought in contact with the mercury by agitation alone, which is not sufficient for amalgamation from these tailings, considering that they are so largely made up of sulphides and other ferruginous impurities; while with this, the mercury is so liable to "flour" and become granular, and thus incapable of taking up the minuter gold. Continued observation and experience shows that a process analogous to hand-rubbing in the washer's dish is necessary for the saving of minute gold; hence the pulveriser should have the property of grinding the slime in intimate contact with the mercury, as in the ordinary

[1] These tables were subsequently, as they should have been in the first instance, coated with sodium-amalgam.

'arrastre,' or else a rubbing apparatus should succeed it in the process of extraction.

At the time of my last visit, the Alpha works were at a standstill, several repairs being in course of operation, and the engine waiting for some fitting to the boiler. The Manager, however, passed several samples of ordinary burnt tailings through the hand-process which clearly showed gold, only part of which was, however, taken up by even the sodium-amalgam, and there was always colour of gold to the last of the rubbing.

The works of the Wynád Prospecting Company are planted a short distance down the slope of the Carcoor cherrum, and a wire rope, some 400 feet long, is stretched from the entrance of the galleries to the works, along which the baskets of vein-stuff are shot to a kiln, where the stone is burnt prior to being the more easily broken up and tipped into the feed-box. The machinery consists of a Husband's pneumatic stamper, driven by a turbine having a fall of about thirty feet of water, and capable of crushing half a ton in eight hours, the working of these being remarkably easy and constant, requiring only such care as a well-trained native and his assistants can give. From the stamping box, the fine sandy slime passes over a series of two amalgamated copper tables, with a mercury trough at the end of each, whence it flows by a spout to the top of the hollow vertical shaft of a grinding concentrator. The bottom of this shaft is screwed into a muller (continuously hollow with the shaft), or inverted truncated cone, revolving inside of a fixed pan, the lip of which is level with the upper edge of the muller. After passing down the shaft, the stuff is ground only in a very inefficient manner in the pan and then agitated, but not rubbed intimately with the mercury, which lies at the lowest level, or out of reach of the grinding surfaces. This defect might certainly be obviated to some extent by filling up the pan with a sufficient quantity of mercury; but this was not found practicable at these works; indeed, this apparatus was found to be of so little use either in grinding or concentration, that its employment was discontinued. To a certain extent, as its name implies, this machine is a concentrator; for the gold and the auriferous sulphides must, perforce, remain at the bottom of the pan longer than the rest of the crushed material, which is carried away by the water; and in this way freer scope is given for amalgamating, but effectual amalgamation, as far as Wynád gold is concerned, is not secured by such poor grinding and agitation.

There is here, in fact, very much the same defect as in the Alpha machinery; in both cases there is a machine which was expected to grind and amalgamate, but the grinding is only well done in the Alpha pulveriser, while no effectual amalgamation takes place in either apparatus. From the pan the stuff passes over a further copper table into a transverse trough, with a further and last supply of mercury. A horizontal pipe, the under-surface of which is perforated, runs along near the bottom of this trough; water is turned on through the pipe with considerable force, and by its rush among the materials at the bottom a violent agitation is caused, the lighter sand is driven off, and a partial concentration is effected in contact with the mercury. Beyond this, a further series

of sloping buddles and riffled troughs intercept the sulphides, until the tailings finally fall into the catch-pit. Here, also, it was found necessary to construct a furnace for the roasting of the tailings, which were again passed through the whole process, commencing with the stamping box; the results were not satisfactory, though the tailings clearly showed an appreciable quantity of gold, much of which, however, could not be saved by the apparatus provided. As usual, hand-grinding and amalgamation gave the best returns; and thus it is evident that a rubbing machine[1] is required, in addition to a pulveriser. Two assays of hand-ground tailings from the reverberatory furnace were very satisfactory, giving averages of 11·66 dwts. and 6·12 dwts. to the ton. Such roasted tailings as I saw at these works were all so stony and slaggy, that they appeared to have been rather smelted than roasted, and were quite as hard as the original vein-stone. Authority on this point appears always to indicate a bright red heat as the limit of roasting, and that the roasted material can be broken up without such force being required as that of the stamper; though of course it should be submitted to this, in order to reduce it sufficiently for the pulveriser. It is also advised[2] that the tailings should be freely exposed to the action of the atmosphere for some months in thin layers, and not piled up in pits, as is the case in the Wynád Works.

The Prince of Wales' Company, as already stated, made use of the Alpha mill; but fortunately the stone raised was rich enough to dispense with extraordinary care in the concentration and amalgamation, which hardly could have been arranged in the time allowed during the lease, or with the small capital at their disposal. Under this administration it was found that the working-power of the driving engine was only sufficient for the crushing of seven tons per diem, or about half the rate originally calculated on.

The following tables are from the published returns of the Companies, or from returns which have been supplied to me by the Managing Directors; and, from my personal knowledge of all the gentlemen concerned, I believe that they have furnished these returns with a firm determination to let the true tale of their efforts be known. Until lately, all these efforts have been unattended with the success they deserved, and no gain has been made, except by the latest adventure, which has had the enormous advantage of working with machinery ready at hand. So far, the work of the latter Company has been crowned with what may be called a success; for, in November last, 50 tons gave an average of over 11, while, in December, 50 tons gave an average of 17 pennyweights, thus showing a decided tendency in the quartz to come up to my average, if not to exceed it.

In the beginning of this paper, the average percentage of gold is given for all the quartz crushed, which is really the truest test of the capabilities of a gold-field; otherwise, between isolated and short operations of particular adventures, where can a line be drawn from which an average should be reckoned? But this generalisation for a whole field is obviously unfair to an

[1] Such a machine is described in the last edition of Raymond's Mining Statistics West of the Rocky Mountains.

[2] Quartz Operator's Hand-book, Randall, New York, 1871.

adventure which has given averages, for large quantities of stone, exceeding those attained in the earlier trials. I would therefore here record a few data regarding the operations of each of the Companies, collated from their tables so that the good points in each may be calmly weighed against the general average referred to.

The Alpha Company crushed, in about eight months, only 769·5 tons of quartz at a cost of Rs. 2,971-6-0 for raising and crushing, and obtained 91 oz. 12 dwts. 12 grains of gold, giving an average of 2·27 dwts. This work, according to the original estimate of 15 tons per diem, ought to have been done in two months and a half, reckoning 20 working days in the month.

The Prospecting Company crushed 99·85 tons, cost not given, in about eight months, and obtained 14 oz. 19 dwts. 19 grains, or an average of 3 dwts. At half a ton a day, the working-power of their stamper, this is a fair rate of work.

The Prince of Wales' Company crushed 322·66 tons in a little over six months, cost not stated, and obtained 164 oz. 17 dwts. 6 grains of gold, or an average of 10·5 dwts. Such work ought to have been done in a little more than a month with the Alpha machinery at the originally estimated rate.

The average cost of raising and crushing one ton of quartz by the Alpha Company was Rs. 2 and Rs. 1 85 respectively. Under the Prince of Wales' Company, the charge for mining was Rs. 4 15, and supposably the same rate for crushing as with the Alpha. In both cases, these rates are far too high. No returns have been supplied as to these charges with the Prospecting Company; but, from the experimental way in which the trials were made, the cost of raising was probably higher than in either of the other adventures, while that of crushing must have been proportionally low, considering that water is the motive-power employed.

In all cases, time has been the most expensive item; the charges for superintendence, pay of engine-drivers, permanent hands, and live-stock are far beyond any estimate which might have been proposed. For instance, in the account of expenditure of one Company, the charges for those amount to Rs. 3,942-12-10 in nine months, when the whole transaction, if properly organised and systematically carried on, even allowing for the delay consequent on putting the machinery in order, should have occupied, at the most, only half this time.

TABLE I.

Memo. of eight months' crushing, Alpha Gold Company Limited.

Month	Quartz crushed.	Total yield	Average yield	Cost of raising	Cost of crushing	TOTAL.
1875.	Tons.	oz. dwts. grs	oz. dwts grs	Rs. A. P.	Rs. A. P.	Rs. A. P.
September ...	99	8 12 0	0 1 17	172 0 0	126 1 6	298 1 6
October ...	40	8 0 0	0 4 0	176 9 6	170 15 6	347 9 0
November ... December ...	269	24 5 12	0 1 19	291 14 0	314 3 6	606 1 6

TABLE I,—continued.

Memo. of eight months' crushing, Alpha Gold Company Limited—continued.

Month.	Quartz crushed.	Total yield.	Average yield.	Cost of raising.	Cost of crushing.	TOTAL.
1876	Tons.	oz. dwts. grs.	oz. dwts. grs.	Rs. A. P.	Rs. A. P.	Rs. A. P.
January ...	175	22 14 0	0 2 14	293 4 6	269 0 6	562 5 0
February ...	170	17 12 10	0 2 1	328 8 0	368 3 0	696 11 0
March ...	20	3 19 15	0 4 0	182 5 0	116 3 0	298 8 0
November* ...	6½	6 9 10	0 19 22	97 2 0	65 0 0	162 2 0
TOTAL ...	769½	91 12 23	0 2 9	1,541 11 0	1,429 11 0	2,971 6 0

* Crushed at the works of the Prospecting Company.

TABLE II.

Memo. of crushings, Wynád Prospecting Company's works.

No. of trial.	Date of cleaning up.	Weight of stone crushed.	Yield of gold.	Rate per ton.	REMARKS.
	1876.	Cwt. qrs. lbs.	oz. dwts. grs.	oz. dwts. grs.	
1	5th October ...	44 0 0	0 9 17	0 4 10	
2	30th „ ...	420 0 0	2 17 21	0 2 18	
3	11th November ..	500 0 0	3 6 6	0 2 15	
5	29th „ ...	185 0 0	0 9 4	0 1 0	Not passed through amalgamator.
6	4th December...	35 0 0	1 3 1	0 16 0	Picked stone; cost Rs. 15 per ton.
7	23rd „ ...	350 0 0	0 16 16	0 1 0	Not passed through amalgamator.
8	28th „ ...	40 0 0	0 4 3	0 2 13	Stone rejected in trial No. 6.
	1877.				
9	6th January ...	175 0 0	0 8 13	0 1 0	Not passed through amalgamator.
10	9th April ...	150 0 0	0 2 6	...	Hand-ground; burnt tailings.
11	21st August ...	140 0 0	3 15 0	...	Mr. Withers' work and selection.
12	25th September ..	90 0 0	0 9 16	...	Tailings from No. 11 not burnt.
13	14th October ...	108 0 0	0 19 12	0 3 15	Jacob, carpenter's, work; cost Rs. 7 per ton.
		1,997 0 0	14 19 19	0 3 0	

TABLE III.

Memo. of assays, Wynád Prospecting Company's works.

Assays of tailings. Weight	Yield per ton. oz.	dwt.	grs.	Remarks.	Assays, various. Weight.	Yield per ton. oz.	dwt.	grs.	Remarks.
lbs.	oz.	dwt.	grs.		lbs.	oz.	dwt.	grs.	
22	0	6	7	Catch-pit, not burnt...	112	0	9	0	Average of 200-ton heap, English assay.
12	0	3	21	Catch-pit, burnt ...	0	0	0	0	
10	0	4	20	Blanket, not burnt ...	10	0	9	8	Same stuff, Withers' assay.
10	0	4	18	Buddle, burnt ...	10	0	2	9	Same stuff, Korumber's assay.
40	0	11	16	Reverberatory furnace, hand-ground ...	5	1	3	0	Korumber's assay, Bear reef No. 2.
112	0	3	8	Reverberatory furnace, not ground ...	5	0	10	0	Korumber's assay, Bear reef No. 1.
112	0	6	3	Reverberatory furnace, hand-ground ...	18	0	2	12	Korumber's assay, sand from trials.
1	0	1	7	Blanket tailings, English assay ...	9	2	5	0	
1	0	1	5	Catch-pit tailings, English assay ...	27	1	0	0	

TABLE IV.

Memo. of crushings, &c., Prince of Wales' Company Limited.

Month.	Quartz crushed.	Total yield of gold.	Average yield per ton	Total cost of mining.	Average cost of mining 1 ton.	Average cost of crushing 1 ton.
1877.	Tons.	oz. dwt. grs.	oz. dwt. grs.	Rs. A. P.	Rs. A. P.	Rs. A. P.
August 17th ... September ... October 13th ...	104·66	14 10 0	0 2 18·5	362 7 0	3 7 8	1 13 9*
November ...	12·00	1 6 12	0 2 5	310 13 6	5 0 2	
Ditto ...	50·00	29 9 0	0 11 19			
December ..	50·00	41 6 0	0 16 12·25	926 12 6	5 14 8	
1878.						
January ..	104·00	77 9 18	0 14 21·6			
February 22nd ..	2·00	0 16 0	0 8 0			
TOTAL ...	322·66	164 17 6	0 10 12	1,600 1 0	4 15 4	1 13 9.

		oz.	Rs.	A.	P.
Specimens of gold in quartz sold in November, about	...	4·35	175	0	0
Ditto ditto December, „	...	4	156	4	0
Ditto ditto Jany. & Feby. „	...	23	920	0	0
Average price of gold from crushings, per ounce	...	...	41	10	8

* Presumed average, taken from Table I, of Alpha Company's results.

NOTES ON THE REPRESENTATIVES OF THE UPPER GONDWANA SERIES IN TRICHINOPOLY AND NELLORE-KISTNA DISTRICTS, BY R. BRUCE FOOTE, F.G.S., *Geological Survey of India.*

The following notes on the most southerly group as yet known of "plant beds" belonging to the upper division of the great Gondwana series, will be found to supplement very considerably the information given by Mr. H. F. Blanford about the "Ootatoor plant beds" in his very interesting Memoir "On the Cretaceous and other Rocks of the South Arcot and Trichinopoly Districts."[1]

These beds, which crop out from below the western boundary of the main area of the cretaceous rocks, were worked out by Mr. H. F. Blanford when in charge of the Madras Party of the Geological Survey of India in the year 1858, 1859 and 1860. They were re-examined by me in the autumn of last year (1877), with the object of comparing them more closely with the various other groups of rocks of similar age which had since then been mapped during the progress of the Survey work northward, along the coast, into the Godavari valley.

The plant remains which characterise these beds, and the discovery of which first led to the separation of the "plant beds" from the overlying lithologically similar cretaceous series, were discovered by the late Mr. Charles Æ. Oldham, to the east of Ootatoor village, and were shortly afterwards recognised by Dr. Oldham, then Superintendent of the Geological Survey of India, as identical (in part) with the species occurring so numerously in the Rajmahal beds of Bengal, and with some of the fossil plants discovered in the oolitic beds of Cutch.

The Ootatoor plants were mostly referred to the genus *Palæozamia*, one of the Cycadeous family; and this is the only name mentioned by Mr. Blanford, presumably because none of the others had then been determined. The plants, though often so favourably fossilised that very delicate markings are perfectly preserved, are almost always very fragmentary in character—often mere shreds of the original plants.

The beds occur in six small detached patches, which all rest directly on the very uneven surface of the gneiss, and form a line running north-east-by-north to south-west-by-south, the extreme ends of which are fifteen miles apart.

As Mr. Blanford has given but little detailed information as to the variety of beds, the following sections will be found useful for comparison with other sections elsewhere. Lists of the fossils obtained by me will also be given further on.

I.—SECTIONS OF THE NAICOLUM PATCH.

Section No. 1 (in descending order).

15. Brown and purple sandstones with obscure plant remains.
14. Clays and shales, buff, light-brown } beds, rolling.
13. Ditto ditto, drab, white and buff } beds, rolling.
12. Sandy shale, hard, purple and brown.
11. Shales and clays, buff and whitish, with kunkur.
10. Shales, gritty, ferruginous.

[1] Memoirs of the Geological Survey of India, Vol. IV, Pt. 1, 1.

9. Shales, gritty, with fine clay in nests.
8. Ditto ditto, buff, drab and white, with reddish yellow, gritty partings.
7. Ditto sandy, grey and drab, with clay galls.
6. Ditto ditto, grey, white and buffy.
5. Sandstones, micaceous, grey, reddish, thick-bedded, dip 10° to 12° east.
4. Shales sandy, white drab, grey.
3. Ditto ditto, buff, drab, red, dip 45° north-east.
2. Gritty beds, with much kunkur.
1. Silt, clayey, mottled white and red.
Gneiss.

This section extends over a distance of 900 paces along the lane running east from Naicolum village.

Section No. 2.

10. Shales and clays, micaceous, grey, white, drab, pale buff, brown, with plant remains.
9. Shales, gritty, brown.
8. Ditto, micaceous, drab.
7. Clays, white, grey.
6. Grits, micaceous.
5. Shales, gritty, micaceous, with kunkur.
Gap in section.
4. Grit, hard, grey, calcareous.
3. Shales, grey and white.
2. Grit, brown.
1. Boulder bed.
Gneiss.

This section is seen in the small rain gully running north-east from the extreme southernmost point of this plant-bed area. The few plant remains found in this section were all obtained in No. 10. Amongst these were a fairly well preserved specimen of part of a frond very nearly allied to (if not identical with) *Otozamites abbreviatus* and a pinnule of *Ptilophyllum acutifolium.* The other plant remains were undeterminable, grassy-looking stalks. Mr. H. F. Blanford describes the plant beds here as abounding in *Zamias,* so probably he had the good luck to hit upon particular beds rich in fossils which escaped me, though I searched very carefully for them. His description gives no clue as to what part of the series he found the fossils in.

From section No. 1, I obtained nothing recognisable on cursory examination, and was prevented by bad weather from making a closer search.

II.—SECTIONS IN THE OOTATOOR-TERANY PATCH.

Both ends of this patch of the plant beds proved themselves rich in fossil remains, representing a considerable number of genera characteristic of the Rajmahal flora. The following section No. 3 gives a good idea of the succession of beds in the southern part of the patch :

Section No. 3.

23. Gritty sandstones, grey, massive.
22. Ditto, coarse, ferruginous, purple to brown, rolling.

21. Gritty sandstones, and shales, grey, alternating.
20. Ditto, buff and drab, false bedded.
19. Ditto, grey and whitish grey, flaggy.
18. Shales, gritty, grey, drab.
17. Gritty sandstones, coarse, ferruginous.
16. Ditto, buff, false bedded.
15. Ditto, grey, drab.
14. Shales, sandy, drab.
13. Ditto, white, grey, buffy.
12. Gritty sandstones, brown, flaggy, with a few pebbles.
11. Ditto, false bedded.
10. Conglomerates and sandstone (local), with red clay in galls and lenticular patches.
9. Pebble and boulder bed (local).
8. Sandstone, gritty, buff, brown.
7. Ditto, ferruginous.

Small fault.

6. Grit, shaley, drab.
5. Conglomerate, gritty, ferruginous, enclosing gneiss pebbles.
4. Grit, fine light-colored, enclosing boulders.
3. Ditto, coarse, ferruginous.
2. Ditto, fine bedded, shaley, brown, buff, pinkish.
1. Boulder bed.

Gneiss.

The direction of this section is, roughly speaking, from west-south-west to east-north-east, and the length about one-third of a mile. The dip is easterly, but shifts several points northward and southward with the rolling of the beds. The average dip is from 12° to 15,° but varies a good deal in parts. The plant remains were mostly obtained from beds Nos. 13 and 14, but a few also from a thin bed of clayey red sandstone, a little distance south of the section locally underlying No. 11.

The fossils obtained at the Terany end of this patch of plant beds were found in the materials excavated in sinking two new *bowries* in the paddy flat immediately east of the villages. As the beds are nearly horizontal, their base is obscured by the water in the wells; but they are probably low down in the series, as they lie close to the gneiss boundary.

The fossiliferous rock is a fine shaley micaceous sandstone of deep buff colour, and unfortunately rather friable, so that the impressions of the plants are very easily effaced. They will be enumerated further on.

III.—The (Kauray) Kári Patch.

A good section of the western end of this patch is formed by a nullah which drains into the tank north-east of Terany.

Section No. 4.

16. Grit, purple (overlaps on to the gneiss).
15. Shales, drab and buff and grey, mottled.
14. Ditto, sandy, buff, with large concretions.

13. Grit, with band of calcareous concretions, some quite gritty.
12. Shales, grey and buff.
11. Ditto, buff, reddish, with gritty partings, locally.
10. Grit, hard, purple, brown.
9. Calcareous concretions, band of, with much kunkur.
8. Shales, sandy or clayey, buff, yellow, grey, white.
7. Grit, hard, purple, orange.
6. Shales, clayey, grey, white, with bands of ferruginous concretions.
5. Grit, hard, purple, brown.
4. Ditto, mottled (with gneiss pebbles).
3. Ditto hard, thin-bedded, orange and purple.
2. Shales, clayey and sandy, grey, mottled, with sandstone partings.
1. Grit, semi-compact, mottled, purple, buff, orange, grey and white, with fragments of felspar, ferruginous concretions, and much kunkur.

Gneiss.

The succession of the beds in the upper or northern part of the section is obscure, but they seem to succeed each other regularly, and to abut against the gneiss, which here rises in a steep bank. The mineral character of the different beds changes so rapidly, that it is very difficult to trace them with certainty where the sections are not very clear and distinct.

A little to the east of the above section the basement bed is of a bright blood-red with grey and white specklings, and the representative of No. 3 on rich red or purple grit. The boulder bed, so characteristic elsewhere, does not occur in this section.

Fossils are not numerous in this part of the Kari patch; the only one found by me was a rather fine frond of *Otozamites*, procured from the buff shale bed No. 8.

IV.—The Coodicaud-Kullpaudy Patch.

The greatest development of the boulder bed at base of the plant series is to be seen to the north-west of Coodicaud, and here, as near Ootatoor, the included boulders are greatly decomposed. The spaces between the boulders are occupied by a fine silt of buff or brownish yellow colour. The following section of the lower part of the series was observed in a rain gully east of Iyalur (Aiyalur):

Section No. 5.

6. Grit, greenish, yellow.
5. Ditto, ditto and drab.
4. Limestone, coarse concretionary, dull-brown, with badly preserved traces of plants.
3. Grit, buff.
2. Grit, silty, buff, with much kunkur.
1. Boulder bed, with buff silt.

The impressions of plants in the limestone are not recognisable. The beds roll about at low angles, but have a general low dip south-eastward. The upper bed is covered by cotton soil, which extends for a considerable distance eastward. Further to the north-east the plant series is more fully exposed in numerous deep rain gullies, and shows, as pointed out by Mr. Blanford, "alternations of micaceous shales and grey sandstones and grits with great gritty calcareous concretions."

The dip is eastward or north-eastward at angles from 8° or 10° up to 15° and 20.° Plant remains are rare; Mr. Blanford failed to find any, but Mr. Oldham was more fortunate; and I too succeeded in finding some in two beds. In the first case, the matrix was a rather coarse friable micaceous shale, and the remains neither characteristic nor preservable. In the second case, a fine-grained, rather soft, buffy-brown, sandy shale near the base of the series yielded well preserved, but fragmentary, remains of *Pterophyllum* sp., of *Ptilophyllum cutchense?* and *Angiopteridium spathulatum*, besides a Cycadeous (?), fruit and stalk-like fragments.

V.—THE DISPUTED BEDS AT MARAVATUR.

According to Mr. H. F. Blanford's views, no true plant beds occur northward of the Coodicaud-Kullpaudy patch just described, but, according to Dr. Oldham's views, another patch of them occurs about a mile to the north of Maravatur (Moraviatoor of Sheet 79). Mr. H. F. Blanford contended strongly that the latter beds were really of cretaceous age, though petrologically very like the true plant beds further south; and based his contention mainly on the fact that he could "not find any remains of plants," while the stratigraphical relations of the disputed beds and the overlying Ootatoor beds appeared to indicate conformity and true sequence. Dr. Oldham, on the other hand, insisted that he had discovered true Rajmahal plants in these disputed beds in 1859, and again when he revisited the place in 1861.

The results I obtained after a most careful examination of this disputed patch of ground compel me to adhere to Dr. Oldham's view, that it is an extension of the true plant beds. Plant remains do unquestionably occur in several of the beds near the gneiss, together with impressions and casts of a small bivalve shell. The plant remains are, it is true, very ill preserved and quite fragmentary, but patient searching yielded a number of specimens which admit of approximate determination; and these represent some of the commonest forms in the undisputed plant beds of Terany and Ootatoor. Had I not found these plant remains, I should have sided with Mr. Blanford, for the stratigraphical evidence of a break is wanting.

The fossil plants that are recognisable in the specimens I obtained are various fronds of *Angiopteridium*, a fragment of a fern very near to *Sphenopteris*, and fragments of *Ptilophyllum*, *Macrotæniopteris ovata* (?), and *Dictyozamites*. I have sent up 19 specimens of plants in all to our Museum from Maravatur, and should have sent many more but that they had crumbled into dust, owing to the cases they were packed in having, together with much of my most valuable luggage, as despatch-box, book-box, gun-case, &c., been soaked in a tank for some while through the cleverness of a cartman. As will be readily understood, when the identity of the source of the materials of which both the plant beds and overlying cretaceous rocks are formed is considered, there is a very strong petrological resemblance between many of the beds in both formations. There is quite as great a variety in mineral character and colour among the members of the plant-bearing series as in a similar thickness of deposits in the cretaceous group. To my mind, they

are by no means so monotonous in composition or colour, as compared to the cretaceous rocks, as Mr. Blanford's description would lead one to believe.[1]

The position occupied by the several patches of Rajmahal beds now described is quite analogous to that of the various other patches occupied by them along the coast as far north as the neighbourhood of Ellore in the Godavari district. There is also very strong resemblance in the petrological character of these beds with many of those occurring in the Chingleput, Nellore, and Kistna districts, as will be pointed out further on. Many beds in those districts are unquestionably of marine origin, as proved by the fossils they enclose; and such beds enclose also numerous plant remains in no wise different in kind, or in state of preservation, from those not associated with marine remains. This throws a doubt on the assumption, that all the Rajmahal beds in Trichinopoly district are of fresh-water origin. Except the negative evidence from the absence of marine fossils from such beds, there is no ground for supposing such beds to be of fresh-water origin; and this latter supposition requires a total rearrangement of the geographical conditions which may, from recent analogy, be supposed to have existed at that period. When Mr. Blanford wrote his Memoir, it is true none of these other Rajmahal formations were known or suspected to be of marine origin; his deduction therefore of their fresh-water origin was natural.

The discovery of a marine fauna in the southern representatives of the Upper Gondwana series was first made by myself when surveying the Sripermatur area west of Madras in 1863. From the nature of the plants there discovered in the same beds of (white or grey) shales with the marine remains, no doubt could remain of their formation being truly of Rajmahal age. Since then still more strikingly marine beds have been discovered containing Rajmahal plants, *e. g.*, the Ragavapuram shales in the Godavari district by Mr. King, Deputy Superintendent, Geological Survey of India (in 1874); also the Vemávaram shales in Nellore district (by myself in 1875); and the Budáváda shaley calcareous grits also in Nellore district (found by me in 1876). The northerly extensions of the two latter formations into the Kistna (Guntoor) district are also of marine origin, and so, too, are the plant-bearing beds further south in the Nellore district at and around Kandullur.

The nature of the small bivalves found in the "disputed beds" at Maravatur has not yet been determined critically; but they look to me, if I may trust my memory to that extent, very much like some minute shells that I found in some of the plant beds north and south of Kandullur, associated with other unquestionably marine shells.

In his interesting paper "On the Age and Correlation of the Plant-bearing Series of India," read by Mr. H. F. Blanford before the Geological Society (of London),[2] he speaks of "beds with marine fossils intercalated with them" (the plant beds); this is not correct, for there is no separation of the beds. Where the marine fossils occur, plant remains occur also, and often in the same hand specimen; and these plant remains are precisely in the same condition, and fossilised

[1] Memoirs, G. S. I., vol. iv, p. 42.

[2] Quar. Journ. Geol. Soc., vol. XXXI, p. 519, 1875.

in the same way, as those occurring in other shale beds, where marine fossils are not found. This association of the plant and animal remains occurs also, and very markedly, in the shaley beds at Vemávaram (in Nellore district), and further north in the Kistna district.

I confess it appears to me to be unnecessary to imagine that any of the beds are of fresh-water origin, simply because of the absence of marine fossils from some of them, when they abound in other beds intimately associated with, and perfectly conformable to, the former. A change of level and of other geographical circumstances, so great as to replace the sea by a lake, or large river, or *vice versâ,* is one of such magnitude, that it would surely produce some stratigraphical discordance of corresponding import. No such discordance is traceable in any of the numerous patches of Upper Gondwana plant beds that I have now seen. The absence of marine fossils from some of the beds should therefore, I submit, be explained in some other way.

For the sake of comparison, I give below several sections from the more northerly patches of Upper Gondwana rocks. The first of these occurs in the banks of the Naggery river at Chittapuram, a little below the junction with the Tritany river, in North Arcot district. The same beds occur in both banks, but they are best seen in the right, or south, bank. The succession of beds in downward succession is the following:—

8. Laterite and quartzite shingle bed.
7. Quartzite shingle, with sandy matrix.
6. Gritty friable sandstone with shaley and kunkury layers; the gritty parts much false-bedded.
5. Quartzite shingle, with sandy matrix.
4. Friable sandstones, with plant remains.
3. Coarse shingle, matrix of sandy clay.
2. Clays, light brown grit, with bands of sandstone and plant remains.
1. Boulder bed, resting on the gneiss which shows a little to the west.

The plant remains were obtained from the corresponding beds on the north bank of the river. They consisted of a small, but broad, leaf, closely resembling *Macrotæniopteris ovata,* from No. 4 of which several specimens were found, and of fragments of fronds of *Dictyozamites* and *Ptilophyllum,* from No. 2.

The sections near Sripermatur are such very shallow ones, that they afford but little material for comparison. The best perhaps is that seen in the Kambam Kal (a channel feeding the great Sripermatur tank), about half a mile west of the Engineer's bungalow. The beds exposed are—

5. Lateritic sands, with quartzite implements.
4. Shales, pure white, compact—the "plant beds."
3. Grits, yellowish, coarse, with shaley partings, much false-bedded, very friable.
2. Shales, sandy, micaceous.
1. Sandstones, gritty, white and greenish, grey, friable.

The last section that I will quote from the Sripermatur area occurs at Vatambakam (Vantambanum of Sheet 78) in the southern part of the area, where a

small headland some 30 feet high juts out from below the Oragidam laterite plateau. The beds here seen are—

13. Laterite gravel, with quartzite pebbles.
12. Clay, white sandy, with concretionary lateritic ironstone.
11. Grit, friable, coarse brown, buff and whitish, with shale and sandstone partings, passing down into—
10. Sandstone, brown and reddish-brown, compact, lateritic and shaley.
9. Sandstone, buff, very fissile and shaley.
8. Clay, sandy, white and pale buff, rather friable with plant remains.
7. Sandstones, shaley, purple and buff with clayey partings.
6. Shale, sandy (local).
5. Clay, white.
4. Sandstone, shaley, purple at top, buff below.
3. Clay white.
2. Sandstones, thin-bedded, buff, more gritty and purple at top.
1. Shales, sandy, whitish, friable.

The plant remains in No. 8 are numerous and well preserved, but very difficult to secure, owing to the very friable nature of the matrix. Among the fossils were two or three species of *Ptilophyllum* and *Angiopteridium*.

There is nothing in the Trichinopoly plant beds that resembles the hard compact shale variety which occurs at several places in the Sripermatur area. In texture and lustre this shale is sometimes almost porcellanic, and when fossiliferous contains the best preserved remains found. A similar variety is common at Vemáveram in the north-eastern corner of Nellore district. Here it is, however, never quite so hard as the hardest forms seen near Sripermatur, but, like them, shows the fossils enclosed in a high state of preservation.

Most of the fossils found in the Sripermatur area and at Vemávaram are covered by a thin film of colour, either red or purple, more rarely brown or black, which does not extend to the surrounding shale or sandstone, so that the organism is strikingly set off. It is very rare for the colour to extend beyond the limits of the organism. This colouring is much less frequent in the Trichinopoly specimens. The vegetable fossils from all the Upper Gondwana formations on the Coromandel coast agree in being very fragmentary, however well preserved they may be in other respects. They were evidently swept out to sea in some condition, and speedily imbedded before decay attacked them.

The Trichinopoly patches show many fewer argillaceous beds than do the more northern ones, especially those in the neighbourhood of Madras and of Guntoor; this may be due in great measure to the different mineral character of the mass of the gneissic rocks which yielded the materials of which these younger rocks were built up. Both opposite the Madras and Guntoor Upper Gondwana areas, coarse, highly felspathic granitoid gneiss constitutes the main mass of the country over many hundred square miles, while the bulk of the gneissic rocks forming the Patchamallays, the high lands which yielded great part of the materials of the Trichinopoly beds, are pre-eminently silicious and ferruginous.

Of the sections to be seen in the patches of Upper Gondwana rocks occurring on the borders of the Nellore and Kistna districts, two only are worth special notice; for, as a rule, the beds are so little exposed, that it is impossible to trace their succession with any certainty. This is due in part to the very slight elevation of the area they occupy, much of it being hardly raised above the general level of the band of coast alluvium, in part also to the very great thickness of cotton soil which extends far and wide over all the older formations. The two best sections are the Vemávaram section (only 8 miles from the coast and 12 miles north-east-by-north of Ongole) and the Boodavadah section, 11 miles to the north of the former. In neither section are the uppermost beds seen, being obscured by the coast alluvium and superincumbent cotton soil. The exposed beds are, in downward succession,—

9. Shales, purple.
8. Do., buffy.
7. Do., softish, brown, white and purple.
6. Do., hard, with red and brown sandstone partings.
5. Do., do., partly flaggy, variegated.
4. Sandstone, parting.
3. Shales, thin, flaggy, buff and white, rather hard, "fish bed."
2. Do., sandy, mottled.
1. Sandstones, shaley, buffy in colour.

The base of the section is also obscured by cotton soil, but about a mile to the west, softish gritty sandstones are seen resting on a hummocky granite gneiss, analogous to parts of the boulder beds forming the base of the Ootatoor plant beds in so many places. Some of these gritty sandstone beds abound in fragmentary plant remains, impressed in red colour on the friable surface. Among the impressions many are not determinable, but perfectly recognizable fragments of *Dictyozamites* (a small form) are very numerous amongst the others. A series of these was sent up in 1875, but from the great friability of the sandstones it is very possible they did not bear the journey. Except in the coarser character of the rock, the general appearance and mode of occurrence of the fossils from these bottom sandstones are a good deal like those of the fossils found at Terany in Trichinopoly district.

The second section in the Nellore-Kistna ground, to be quoted for comparison with the Ootatoor plant beds, occurs at Budaváda in Nellore district, 25 miles north-north-east of Ongole, and 3½ miles west-north-west of the travellers' bungalow at Inkolu on the old Madras-Guntoor road. This section seems to take in the whole of the Upper Gondwanas in this region, but is not by any means as distinct as might be wished, and I offer it as an approximation to the truth and as liable to possible modification hereafter. The section is based upon the results of examination of a series of wells, supplemented by a few poor outcrops and small stone pits. The obscurity is due to the great thickness of cotton soil over the eastern half of the section.

The section which extends from half a mile west of Budaváda (Boodhawadah of Sheet 76) runs due east for the first half of its length, and then turns north-east up to the village of Pávulur, the total length being 2½ miles. The series of beds

here seen, and which I divide into three groups, is thus arranged in downward succession:—

PAVULUR GROUP ...	9.	Sandstones, friable, coarse reddish-brown.
	8.	Do., hard, greenish-black, calcareous, slightly shelly weathers grey or brown.
	7.	Do., friable, drab, pale brown.
VEMAVARAM GROUP ...	6.	Shales, various, hard and soft, mottled in parts, generally light grey in colour.
BUDAVADA GROUP ...	5.	Sandstones, gritty, calcareous and full of shells, rather hard and, tough when fresh.
	4.	Do., shaley, friable, drab, buffy.
	3.	Do., hard, brown, alternating several times with shaley beds.
	2.	Do., massive, hard, brown.
	1.	Do., pebbly, outcrop much weathered.
		Gneiss

The general dip is easterly, at varying and generally very low angles. Beds Nos. 4, 5, 6, and 8 contain marine shells; Nos. 5 and 6 contain plant remains as well, and No. 9 plant remains only.

The Vemávaram shales, I believe to be represented by the shales No. 6, and these latter do not differ much, as far as seen, from many of the softer beds in the Vemávaram section, and they resemble many of the shales in the Ootatoor group. The shelly sandstones, No. 5, are utterly unlike anything as yet known in any of the other Rajmahal areas throughout India.

Whether the three groups into which the plant beds of the Nellore-Kistna area here show themselves to be naturally divisible can be correlated with the three groups Mr. King has established for the Upper Gondwanas of the Godavari district remains to be seen, when the flora and fauna of the more northerly series shall have been worked out. I am inclined to doubt it at present. Of the petrological agreements there can of course be no doubt, but the palæontological evidence of the most important plants, and of the very interesting crustacean of the genus *Eryon* which I discovered at Vemávaram, appear to me to indicate that the Vemávaram group is of the same age, and not newer than Mr. King's Golapilly sandstones in the Godavari district, which Dr. Feistmantel regards as a true Rajmahal formation. I look upon the Vemávaram group as the true marine representative of the Rajmahal formation proper. My reasons for so thinking I will not discuss here at length, but reserve them for a fuller account of the Nellore-Kistna Upper Gondwana groups, which I am now engaged upon.

None of the "plant bed" areas of the Madras Coast has been exhaustively searched, and further research may yet add largely to their floras and faunas; but such further research is not likely to be undertaken by members of the Geological Survey, at any rate for a very long time. The collections we now possess must therefore for the present be assumed to represent fairly the real contents of the several groups of beds. By means of the rough lists of fossil plants from the Ootatoor group of patches severally, the Sripermatur area generally, and

Vemávaram and Budavada severally, which I give below, the respective floras may be compared roughly.

A few facts concerning the distribution of the leading plants which the mere lists do not show may be pointed out in conclusion of my notes. *Dictyozamites* is a genus very rarely found in the Ootatoor group of beds; it is rather more frequently met with in the Sripermatur area, but by no means a common plant there; at Vemávaram, on the contrary, it is one of the most numerous, and shows considerable varieties of form and size. *Angiopteridium spathalatum* is very common at Terany, and occurs in most of the other Ootatoor localities; it is rather uncommon in the Sripermatur area and one of the rarest forms seen at Vemávaram. The form most peculiar to the Sripermatur group, where it occurs frequently, is one I take to be a Conifer hitherto undescribed. This form, which has some resemblance in the arrangements of the leaflets on the stalk to *Taxites tenerrimus*, Feistmantel, figured in the Flora of the Jabalpur Group, but greatly exceeds that species in size, is very rare at Vemávaram, and was not found at all in any beds of the Ootatoor area. *Echinostrobus rajmahalensis* is numerously and remarkably well developed at Vemávaram: it is rare in the Sripermatur area, and absent from the Ootatoor plant beds. Similarly the genus *Pterophyllum* is much better represented both in number of species and specimens at Vemávaram, than either at Sripermatur or in the Ootatoor area.

Dr. Feistmantel considers the Sripermatur group and Trichinopoly or Ootatoor plant beds as equivalents of Mr. King's Ragavapuram beds (Godavari district), a view in which I am quite prepared to agree with him. As already mentioned with reference to my Vemávaram crustacean, which he described as *Eryon* Comp. *Barrovensis*, he has, owing to some unfortunate confusion of the collections, looked upon the Sripermatur and Vemávaram fossils as both coming from the vicinity of Madras, though in reality belonging to localities more than 200 miles apart. When he comes to separate them, I quite expect he will see the necessity of looking upon the Vemávaram beds as rather older than both the Sripermatur and Ootatoor plant beds.

The following lists give the fossils collected by me from the several patches of the Ootatoor plant beds; their determination is of course only preliminary, the final one having yet to be made by Dr. Feistmantel at the Museum in Calcutta, where they can be compared with the type specimens of all the Upper Gondwana floras at present known. The several localities are arranged in their geographical sequence from south to north. In drawing up and correcting these lists, I have of course availed myself as much as possible of Dr. Feistmantel's very valuable monographs.

1. NAICOLUM.

Ptilophyllum acutifolium.
Otozamites abbreviatus ?
Branching leaf-like stalk.
Grass-like branching (dichotomous) leaflets, very delicate.
Stalk with central groove.

2. OOTATOOR.

Cyclopteris ?
Alethopteris indica.
Angiopteridium spathulatum.
Macrotæniopteris ovata ?
Zamites ?
Ptilophyllum acutifolium.
Pt. cutchense ?
Otozamites ?
Palissya, sp.
Seeds or small fruits, numerous; Cycadeous ?
Stalk ribbed.

3. TERANY.

Sphenopteris, sp.
Alethopteris indica.
Angiopteridium spathulatum.
Macrotæniopteris, sp.
M. ovata ?
Pterophyllum, sp.
Pt. distans ?
Ptilophyllum acutifolium.
Dictyozamites indicus.
Otozamites, sp.
Pallissya indica.
Cheirolepis ?
Seeds or small fruits.
Stalk-like fragments of various shapes.

4. KARI (KAURAY) SOUTH PATCH.

Otozamites, sp. ? *abbreviatus?*

5. KUDIKAD (COODICAUD)-KULLPAUDY PATCH.

Angiopteridium spathulatum.
Pterophyllum, sp.
Ptilophyllum cutchense ?
Fruit or seed, cycadeous?
Ribbed stalk of— ?

6. MARAVATUR.

Sphenopteris, sp.
Angiopteridium spathulatum.
Macrotæniopteris ovata ?
Ptilophyllum acutifolium.
Dictyozamites indicus.

Lists of the fossil plants from the Sripermatur and Vemávaram groups and from Budaváda are added, to assist in comparing all the groups.

SRIPERMATUR GROUP.

Sphenopteris, sp.
Pecopteris ?
Angiopteridium spathulatum.

Macrotæniopteris, sp.
Pterophyllum, sp.
Ptilophyllum acutifolium.
Pt. cutchense?
Otozamites, sp.
Dictyozamites indicus.
Palissya, sp.
Echinostrobus rajmahalensis.
Grassy stalks.
Scales or bracts. ? *Araucarites.*
Seed vessels.
Coniferous leaves, undetermined.

VEMAVARAM GROUP.

Sphenopteris, sp.
Dicksonia, sp.
Cyclopteris? sp.
Alethopteris indica.
Angiopteridium spathulatum.
Macrotæniopteris ovata.
M. sp.
Pterophyllum distans?
Pt. sp.
Pt. fissum.
Zamites proximus.
Ptilophyllum acutifolium.
Pt. cutchense.
Otozamites, sp.
Dictyozamites indicus.
Palissya indica.
Cheirolepis?
Echinostrobus rajmahalensis.
Araucarites, sp. (*? macropterus.*)
Cunninghamites dubiosus?
Coniferous leaves, undetermined.

The plant remains obtained from the shelly grit No. 5 at Budaváda were :—

Angiopteridum spathulatum.
Ptilophyllum acutifolium.
Otozamites abbreviatus?
Dictyozamites indicus.

The shales No. 6, the apparent equivalents of the Vemávaram shales, yielded :—

Pterophyllum sp.
Ptilophyllum acutifolium.
Pt. cutchense.
Palissya indica?

The list of Vemávaram fossils was drawn up from only a small part of my collections, and is therefore far from complete, but, as it is, it shows a far greater wealth of form than appears in any of the other localities.

SENARMONTITE FROM SARAWAK.

When recently arranging the Indian and foreign ores of antimony in the Geological Museum, I found, amongst those from Sarawak, in Borneo, which consist mainly of the sulphide and native antimony, a specimen which contains more than one oxide. It is about half a pound in weight, and consists of native antimony with *stibnite*, greyish-white and grey filamentous tufts, which appear to be *volentinite*, but which are only distinctly visible under the lens, and cannot be isolated for examination, *senarmontite* and *cervantite*. The first four are rather intimately mixed up, but small fragments of the *senarmontite* are separable, sufficiently large for satisfactory determination. It occurs both massive and in crystals, which are unmodified *octohedrons*: the larger of these are about a fiftieth of an inch in diameter; the hardness is about 2, the colour of the massive portion is white and greyish, with resinous lustre; the crystals are grey and translucent, with sub-adamantine lustre on the faces. On charcoal the mineral gives an abundant coating of antimonious oxide; it dissolves in hydrochloric acid, the solution yielding a white precipitate with water and an orange-red one with hydrosulphuric acid. I am not aware that *senarmontite* has been previously noticed from Sarawak, and hence put the above observation on record.

F. R. MALLET.

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THE SURVEY.

July 15th, 1878.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1878. [May.

On the Geology of Sind, (second Notice,) *by* W. T. Blanford, A. R. S. M., F. R. S., *Geological Survey of India.*

Introduction.—A brief account of the Geology of Sind, so far as the structure of the country had been ascertained by one short season's work, was given in the Records of the Geological Survey for 1876.[1] Two whole seasons, 1875-76 and 1876-77, have since been devoted by Mr. Fedden, and one season and part of a second by myself to the geological examination of the province, and, as might have been expected, several additions of more or less importance have been made to our previous knowledge, whilst in a few cases it has been found that our first conclusions were incorrect. As before, Mr. Fedden's notes are combined with my own, and I am indebted to my colleague for a large proportion of the observations made. Mr. Fedden has also added much to our knowledge of the fossil fauna by his collection and examination of the fossils, but the details must be deferred for the present.

The sub-division of the tertiary series in Sind into Manchhar, Gáj, Nari, Khirthar and Ranikot groups holds good, although the boundaries between the various sub-divisions have proved, in parts of the province, to be less distinct than in the Khirthar range, and there is the same remarkable appearance, that all the different tertiary formations are only of local value, and that all tend to pass into each other at a comparatively short distance from each typical section, which has been already noticed by Mr. Medlicott in the corresponding formations of the Punjab.[2] Some slight modification in the geological horizon

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[1] Vol. IX, pp. 8-22.

[2] Rec. G. S. I., IX, pp. 50, etc.

attributed to the lower Manchhar beds has also been rendered probable, but in general there appears every reason for accepting the views put forward in the former paper as to the correlation of the different tertiary groups in Sind. It has, however, been found that, in the original classification, rocks were included in the Ranikot group, which belong in fact to a much lower horizon, and three small groups have been established beneath the lower tertiary sub-division and referred to the cretaceous epoch.

Errors in previous paper.—Before proceeding to notice the additions since made to the Geology of Sind, it will perhaps be best to call attention to a few statements in the previous paper which further examination of the country has proved to be untenable. The corrected general section will be found below, but there are a few details requiring alteration, besides the entire re-arrangement of the beds included in the first notice in the Ranikot group.

The supposed unconformity between the Gáj beds and the Nari group at Tandra Ráhim Khán, west of Sehwán,[1] appears doubtful. Further examination of the junction between the two groups has failed to show any clear evidence of unconformable overlap.

The basaltic lava flow[2] is now shown to be at the base of the Ranikot group, and not intercalated, the beds below the volcanic rock being of different age.

Another error is in the statement[3] that the Khirthar rocks compose several ridges near the Habb river, the southernmost of which terminates at Cape Monze. It is true that some ridges near the Habb consist of Khirthar rocks, and that the ridge west of the river, not far from the mouth, is composed of that formation, but the range terminating at Cape Monze proves on re-examination to be of Gáj beds resting on Nari. The mistake was due to the rocks having been first examined before the different sub-divisions of the Sind territories had been made out.

General section of rocks in Sind.—The following is the general section of the Sind rocks as corrected, the thickness of each group being estimated, as usual, where the beds are best developed. Very nearly, if not quite the full dimensions given, from the base of the lower Khirthar to the top of the Manchhars, are, however, exposed on the Gáj river, where, below the beds classed as lower Khirthars, nearly 4,000 feet of shales and limestones are seen, which probably belong to cretaceous formations:—[4]

[1] Rec. G. S. I., p. 16.

[2] *l. c.*, p. 22.

[3] *l. c.*, p. 18.

[4] In some brief notes published in the Proceedings of the Asiatic Society of Bengal for January 1878, pp. 4, 6, all these beds were classed as lower Khirthars, and the thickness of the group estimated at 10,000 feet, but subsequent study of Dr. Cook's descriptions of the Kelat rocks has shown that the unfossiliferous lower beds in the Gáj section may, like some very similar rocks south of Kelat, be really cretaceous.

Name.	Sub-divisions.	Approximate thickness.	Supposed geological age.	REMARKS.
1. Alluvial, &c. ...	... ..	Unknown ...	Recent and post-tertiary.	
2. Manchhar ...	Upper ..	5,000 ...	Pliocene ...	Apparently representative of the Siwaliks proper.
	Lower ..	3,000 to 5,000	Lower pliocene or upper miocene.	
3. Gáj ...		1,000 to 1,500	Miocene.	
4. Nari ...	Upper ...	4,000 to 6,000	Lower miocene?	
	Lower ...	100 to 1,500	Upper eocene.	
5. Khirthar ...	Upper ...	500 to 3,000	Eocene ...	Nummulitic limestone.
	Lower ..	6,000? ...	Ditto.	
6. Ranikot ...	...	2,000 ...	Lower eocene.	
7. Trap ...	......	40 to 90 ..	Upper cretaceous...	Representative of Deccan and Malwa trap.
8. Cretaceous ...	*Cardita Beaumonti* beds	350 to 450	Cretaceous ...	
	Sandstones..	700 ...		A bed of trap interstratified with the sandstone.
	Hippuritic limestone ...	320 ...		Base of lower group not exposed.

Cretaceous beds.—The only part of Sind in which rocks of pre-tertiary age are known to exist is in the range of hills running south from Sehwán. Various portions of this range are known by local terms, such as Dharan, Tiyún, Eri, Surjána, &c., but amongst the people of the country there is no name for the range as a whole. By Europeans the northern portion is sometimes called the Laki range, from the town of Laki, near the northern extremity, and for want of a better name this may be accepted. The old fortress of Ranikot is in this range.

The Ranikot beds themselves, it may be mentioned, as was already pointed out in the previous paper, extend over a considerable area to the east of the Laki range, and southward as far as Tatta. They are, however, not exposed anywhere in Upper Sind. The area of the beds beneath the Ranikot group extends northwards from the fortress of Ranikot to within four or five miles of Laki, a distance of about 22 miles. The outcrop, however, is not quite continuous, for the trap and underlying beds are covered up in places by the Ranikot group. The Hippuritic limestone, the lowest rock known to occur, is only exposed in a single locality. The range is very difficult of access, and there is a permanent supply of sweet water at only one spot, the fortress of Ranikot.

The spot where the Hippuritic limestone is exposed is at a place called Barrah, about 15 miles north of Ranikot. The range here consists of three parallel ridges. The eastern of these faces the plain sloping to the Indus, and consists of vertical or nearly vertical Khirthar limestone, on which, to the eastward, Manchhar beds rest unconformably. To the westward, Ranikot beds come in below

the representation of this great volcanic formation in Sind is far from improbable. The question as to whether the Ranikot trap belongs to the Deccan series may now be answered in the affirmative. There is conclusive evidence that this rock is interstratified and not intrusive, for it occupies precisely the same position above the highest *Cardita beaumonti* beds, and below the base of the Ranikot group, for over 20 miles, and appears to be conformable with both, whilst not a single vertical dyke has been noticed in the country. The mineral character of the basalt is precisely that of a very common form of the Deccan trap, whilst two mineral peculiarities—the occurrence of amygdala, surrounded by green earth, and of cavities containing quartz crystals, with trihedral terminations—are both characteristic of the trap rocks of Western India. The geological position also at the base of the tertiary series corresponds with that of the trap series in Cutch and Guzerat.

It is clear, however, that the thin flows of basalt in Sind can only represent a portion of the great Deccan trap period, and the lower band in the cretaceous sandstones indicates that all the upper cretaceous beds between the two trap flows were, in all probability, contemporaneous in origin with the Deccan trap series. If now the age of the *Cardita beaumonti* beds has been rightly determined as upper cretaceous, the identification of the Sind representative beds confirms the views previously held by myself, but by no means generally accepted by my colleagues,[1] as to the cretaceous age of the lower portion, at all events, of the Deccan trap series.

Ranikot group.—It was mentioned in a postscript to the previous paper in the Records[2] that the highly fossiliferous brown limestones seen north-west of Kotri and near Jhirak (Jhirk or Jerruck) and Tatta must be classed with the Ranikot group, and not with the Khirthar. A list of fossils obtained from these brown limestones was given,[3] but from this list two species must be removed, viz., *Cardita beaumonti* and *Nautilus labechei*, the species thus identified (the identification is doubtful in the case of the *Nautilus*) being from the olive shales now classed as cretaceous. It was also noticed in the postscript that south of Ranikot there is distinct unconformity between the Khirthar limestone and the Ranikot group, the upper members of the latter being deficient in the Laki range, and there being at one place evidence of the lower group having been slightly disturbed and denuded before the deposition of the Khirthar limestone. The break between these two formations is, however, probably not indicative of any great interval in time, for several of the Ranikot fossils pass upwards into

[1] Oldham: Rec. G. S. I., IV, p. 77; Wynne: Mem. G. S. I., IX, p. 48. I have lately had occasion to go over all the evidence again when writing a chapter on the Deccan traps for the Manual of Indian Geology, and it appears to me that the arguments in favour of considering the traps tertiary are weaker than I at first supposed. Only one fact of any importance, so far as I know, has ever been adduced: the supposed identification of certain freshwater shells in the intertrappean beds of the Deccan with forms found in the lower eocene plastic clay of Belgium. Apart from the question, a very important one, whether freshwater shells afford trustworthy evidence of age, I greatly doubt the validity of the identification.

[2] Vol. IX, p. 21.

[3] *l. c.*, p. 14.

the Khirthar beds. *In some cases, it is true, there does appear to be a change of* species: thus *Eurhodia morrisi*, a common Ranikot echinoderm, appears to be represented by *E. calderi* in the Khirthar beds, but still there is much evidence of transition, for the lowest Khirthars near Jhirk and Tatta have much the character of the Ranikot limestones, and there is a gradual passage from the one to the other; so much so indeed, that Mr. Fedden has found it difficult to the southward to determine any exact limit between the two, and to map their boundaries.

All the lower portion of the Ranikot group consists of soft sandstones and shales, much variegated in colour. The only fossils found are land plants; many of the shales are pyritous, and gypsum is of frequent occurrence. It appears highly probable that these beds are of fluviatile origin, and their occurrence immediately above the trap may indicate that the latter was of subaërial formation in Sind, as elsewhere.

CRETACEOUS AND LOWER TERTIARY BEDS OF BALUCHISTAN.

In 1875, from the top of the Khirthar range in upper Sind, lower beds were seen cropping out west of the British frontier from beneath the Khirthar limestone. At that time, owing to political complications, there was a difficulty in visiting any part of Baluchistan; but in 1876-77, this difficulty having been removed, I was enabled to examine the sections on the upper Gáj, the only river which actually cuts through the Khirthar range. The beds beneath the Khirthar limestone at this spot proved to be utterly different from those seen in the same relative position in the Laki range. The following is a rough section of the beds on the upper Gáj, with their approximate thickness by estimate:—

KHIRTHAR ...	1. Massive nummulitic limestone forming the crest of the Khirthar range	1,200
	2. Shales, marls, and clays, mostly dark olive in colour and abounding in *Nummulites*	500
	3. Hard grey limestone with *Nummulites*	60
LOWER KHIRTHAR.	4. Argillaceous limestone, shales, and clays, olive and bluish grey in colour, abounding in *Nummulites*	400
	5. Unfossiliferous olive and bluish grey clays and nodular shales; no limestone bands	1,500
	6. Pale-brown sandstones in thick beds, with traces of vegetables ...	1,000
	7. Fine greenish white sandstone and shale, some of which is carbonaceous	500
	8. Dark-brown limestone and dark-green argillaceous beds, with *Nummulites*	100
	9. Pale-grey argillaceous limestone, with but few fossils. One band towards the base contains *Nummulites* and *Alveolinæ* ...	200
	10. Fine dark-coloured shales, unfossiliferous	3,000
? CRETACEOUS	11. Very fine grained homogeneous thin-bedded limestone, white, red, grey or ochrey in colour, unfossiliferous, forming a conspicuous range of hills	1,200
	12. Hard grey shales, with calcareous bands, from an inch or two to a foot in thickness	2,500
		12,160

Not a single bed below the Khirthar limestone (No. 1) can be recognized as identical with any of the formations in the Laki range, although the distance between the two localities is only about 90 miles. In the upper Gáj section, there are no fossiliferous brown limestones, no trap, no olive shales with *Cardita beaumonti*, no dark ferruginous sandstones nor hippuritic limestone. The sandstones Nos. 6 and 7 may represent the lower Ranikot beds, but the resemblance is not great, and there is no palæontological connexion between the two.

The examination of the section was hurried, and it is far from improbable that some fossiliferous bands may have been overlooked, but no distinct break in the sequence was detected; perhaps for want of palæontological evidence. The division between upper and lower Khirthar, and between the latter and the supposed cretaceous beds, is arbitrary; the limestones No. 8 contain the same species of *Nummulites* as Nos. 2, 3, and 4, and no fossils were found below No. 9. The sole reason for distinguishing the 6,000 feet of beds, from No. 5 to No. 10 inclusive, as lower Khirthars, is that, as the nummulitic limestone No. 1 is the same bed at the Gáj as in the Laki range, some of these lower beds must represent the Ranikot group. At first it was supposed that all the lower beds on the upper Gáj section were tertiary, and the lower Khirthar beds were estimated to have a thickness of 10,000 feet, but on subsequently reading more carefully Dr. Cook's account of the geology of Kelat,[1] and Dr. Carter's notes on Dr. Cook's discoveries,[2] it appeared to me that the peculiar fine-grained banded limestones No. 11 must be the same as some red and white limestones extensively developed at no great distance to the north-west. These red and white limestones pass down into some argillaceous beds (perhaps the same as No. 12 of the above section), in which Dr. Cook found *Ammonites*, and he consequently classed both rocks as mesozoic.

It is probable that the beds below the Khirthar limestone occupy a large tract in Baluchistan to the west of the Khirthar range, for similar beds are seen to the westward from the crest of the hills as far north as Darhyáro. Again, west of the Habb river, forming the western boundary of lower Sind, the whole Khirthar formation appears composed of shales, marls, and sandstones, closely resembling the lower Khirthar beds of the upper Gáj section, and an enormous mass of similar beds is found to the westward in Makrán.[3] A peculiar banded red and white limestone, so closely resembling that on the upper Gáj that these two are probably identical, forms a small hill at Gadáni on the sea-coast, about 25 miles north-west of Karáchi.

Khirthar group.—The nummulitic limestone of the Khirthar and other ranges in Sind varies much in thickness, and the original estimate of 3,000 feet may have been excessive, though it is doubtful whether it is too high in the northern part of the Khirthar range, where the limestone must be very thick. At the Gáj, as we have seen, this bed does not exceed 1,000 or 1,200 feet in thick-

[1] Bom. Med. & Phys. Soc. Trans. November 1860. I am indebted to Dr. Cook for a copy of this interesting paper.

[2] Jour. Bom. Br. Roy. As. Soc., VI, p. 184.

[3] Eastern Persia, II, pp. 460, 473.

ness, and farther south it diminishes still further. In the Laki range it is probably not more than 500 or 600 feet, and towards Jungshahi and Tatta it is perhaps even less. Here it rests upon Ranikot beds. But to the westward in the Habb valley the Khirthar limestone disappears entirely, and it appears to thin out within the space of a very few miles. The Khirthar range is composed of the limestone throughout, and terminates to the southward inside the province, near a police post called Karchát, about 50 miles south by a little west from Sehwán. The southern extremity of the range, like several other ridges, is an anticlinal, so that the thickness of the limestone is not seen, but it must be considerable, and can scarcely be less than 500 or 600 feet. About 8 miles west of the Khirthar, the top of the ordinary limestone is seen underlying Nari beds, but in the next low ridge to the westward, only about 4 miles farther, the Khirthars are brought up by a fault, and the typical pale-coloured limestone is found to be completely wanting, and replaced by dark-coloured grey limestones containing *Echinodermata* and *Nummulites,* and interstratified with shales and sandstones precisely like those of the Nari group. A few miles farther west, in the Hamlig range, about 25 miles from the Khirthar, not a trace of the massive Khirthar limestone could be detected. The locality is beyond the Sind frontier, and the examination was so brief, that some fault may have been overlooked, but at this spot, and in some other localities further south, the Nari sandstones appeared to pass downwards gradually into shales and sandstones, with some beds of marl and dark-coloured argillaceous limestones, containing the typical Khirthar nummulites, *N. granulosa* and *N. obtusa,* &c. These beds precisely resemble some of the beds below the Khirthar limestone on the upper Gáj. The brown and yellow Nari limestones, too, are only faintly represented towards the base of the group by thin bands containing *Orbitoides papyraceus.*

Nari group.—No alteration is necessary in the general description of this group. Throughout the Khirthar range, the whole upper portion, 4,000 or 5,000 feet thick, consists of sandstones, with a few scattered beds of shale or conglomerate, and destitute of fossils, with the exception of a few vegetable markings, too imperfect for recognition. The lower sub-division of the group varies in thickness from 100 or 200 feet to as much as 1,500, and consists of shales and thin bands of sandstone, with brown and yellow limestones; the latter chiefly developed towards the base, and containing *Nummulites garansensis, N. sublævigata,* and *Orbitoides papyraceus* (or *fortisi*).

It has already been mentioned that in the Habb valley, in south-western Sind, there is a gradual passage from. the upper Khirthar into the Nari beds, and there is in the same area an equally evident tendency to a passage between the Nari and Gáj groups. The Nari group in the Habb valley is probably as thick as in the Khirthar range; but although the prevailing rocks are still sandstones, brown limestones with *Orbitoides papyraceus* are found in the middle of the group, instead of being confined to the lower portion, whilst the typical limestone bands at the base of the group appear to be ill developed. Now, Mr. Fedden noticed some time since that bands of limestone, with apparently the same *Orbitoides,* are found in the Gáj group; and in the upper part of the Nari group bands of marine fossils occur, containing Gáj species, such as *Ostrea multicostata*

and *Pecten subcorneus.* The boundary between the two groups is consequently, to some extent, arbitrary.

On the other hand, Mr. Fedden has observed at one spot on the west side of the Laki range, a few miles from the northern extremity of the range near Sehwán, distinct unconformity between the upper and lower Nari groups, the sandstones forming the higher portion of the group resting upon the denuded edges of the brown limestones composing the lower sub-division. This is an excellent example of the manner in which the sub-divisions of the tertiary series change, the groups of one locality passing into each other, and new breaks occurring. It should be remembered that the Nari beds are entirely wanting east of the Laki range, and Manchhars, with, in places, a thin representative of the Gáj beds at their base, rest unconformably on Khirthars.

Gáj group.—There is but little to add to the general description of this group also. A measured section of the beds on the Gáj river, where they are especially exposed, shows that the whole thickness of the group is but little less than 1,500 feet at that spot. To the northward the thickness of the Gáj beds must be less, and it is probably smaller in lower Sind also. On the Gáj the greater part of the whole thickness consists of sandy shales and clays, with gypsum, the hard limestone beds, though far more conspicuous, being only subordinate. In the Habb valley however, where the Gáj beds form extensive plateaus, surrounded by scarps in which the rocks of the group are well exposed, the mass of the Gáj strata appears to consist of limestone, and the boundary between them and the Nari, with which, as has just been noticed, bands containing Gáj fossils are interstratified, has been drawn at the base of the limestones. At one spot, a thickness of 500 feet, entirely composed of limestone, was measured (by aneroid) at the base of the group, and this thickness seems to include the greater portion of the Gáj strata in this locality.

It has already been mentioned that the supposed unconformity between the Gáj and Nari groups west of Sehwán at Tandra Ráhim Khán proves, on further examination, to be doubtful. But the Gáj group in the country south of Sehwán completely overlaps the Nari in places, and rests upon Khirthar beds. In this country, however, the Gáj itself is but poorly represented, and frequently is either entirely wanting, or appears as merely a thin band at the base of the Manchhar group.

The passage from Gáj to Manchhar, despite the unconformity shown by overlap, and the presence of Gáj pebbles in Manchhar beds, is locally just as complete as any of the other cases of transition already mentioned. In the paper published in 1876, the transition beds containing estuarine shells in the Khirthar range were mentioned. Some of the estuarine shells are by no means confined to this belt; *Corbula trigonalis*, for instance, occurs in beds near the base of the Gáj group, and has also been found in one band in Manchhar rocks, about 300 or 400 feet above the top of the Gáj. As will be shown presently, there is in the neighbourhood of Karáchi even stronger evidence of the close connection between Manchhar and Gáj beds.

Although the number of Gáj fossils have been somewhat increased, the additions have been less extensive than in the case of many of the other groups.

Amongst the most important additions are, *Vicarya verneuili*, found by Mr. Fedden in some of the upper beds of the Gáj section; a small crab, *Typilobus granulosus*, originally described by Dr. Stoliczka from Cutch,[1] and several of the corals described by Professor Martin Duncan in 1864. All tend to support the opinion that the Gáj beds are miocene, and rather upper than lower miocene.

Manchhar group.—The additions to our knowledge of this group are of more importance. Some of the most interesting have been already noticed in these "Records" and in the "Palæontologia Indica" in the shape of descriptions by Mr. Lydekker[2] of the mammalian remains obtained by Mr. Fedden and myself. During the last season that I was engaged in Sind, Hira Lal, one of the native assistants of the Survey, was attached to my camp, and he succeeded in finding a considerable number of specimens, chiefly small fragments, but including several teeth. Some Baluch shepherds also, living along the Laki range, were induced to collect, and altogether, although the bones and teeth are rare, and but few of those found are recognizable, sufficient material was collected to enable a considerable number of species to be identified by Mr. Lydekker. The comparison of these with the comparatively well known Siwalik fauna has shown a striking difference; most of the species being different, and the general facies of the Manchhar fauna being much older. This distinction is, I think, explained by the geology.

The possibility of a sub-division of the Manchhar group was noticed in 1876.[3] Although it is very difficult to draw an absolute line of separation, there can now be no doubt that the Manchhars may be divided, somewhat roughly it is true, into an upper and a lower sub-group. The lower consists mainly of the characteristic grey sandstone, with occasional red sandstones, and, towards the base, brown or grey and red clays; the latter, however, are of small thickness compared with similar beds in the upper sub-group. Conglomeratic bands are common, and are frequently ossiferous, but they chiefly contain nodules of clay and soft sandstone, and no nummulitic limestone pebbles have been detected in them. It is from these beds that nearly all the mammalian fossils found in the Khirthar range have been derived.

The upper sub-group, where it is best seen in the northern portion of the Khirthar range, is thicker than the lower, and consists principally of beds of orange and brown clay, with subordinate bands of sandstone and conglomerate. The sandstones are usually light brown, but occasionally grey beds occur, like those characteristic of the lower sub-division. The highest part of the formation contains more sandstone and conglomerate, and the whole is capped by the massive conglomerate, which forms the ridge extending along the edge of the Indus alluvium. These conglomerates of the upper Manchhars differ from those of the lower by containing pebbles of nummulitic and Gáj limestone. Bones are rare, and only a few fragments, too imperfect for identification, have been found.

[1] Pal. Ind., Ser. VII, p. 15, Pl. III, figs. 3—5.

[2] Rec. G. S. I., IX, pp. 91, 93, 106; X, pp. 76, 83, 225; XI, pp. 65, 76, 77, 79, &c.; Pal. Ind., Ser. X, pt. 2.

[3] Rec. G. S. I., IX, p. 17.

In lower Sind, whence a large proportion of the mammalian remains have been procured, this sub-division of the Manchhars has not been traced; the beds are poorly exposed, and it is by no means clear that in this ground, where the lowest Manchhars rest unconformably on the Khirthars, the two sub-divisions can be distinguished by the presence or absence of nummulitic limestone pebbles. Several of the fossil forms, however, are identical with those found in the lower Manchhars to the northward, and there can be no reasonable doubt that the fossiliferous beds are on the same horizon. That the Manchhar beds are probably much less developed in lower than in upper Sind is shown by the circumstance that the section of the group, which can scarcely comprise less than 8,000 to 9,000 feet of beds, west of Lárkána and Mehar, has diminished to about 3,000 feet at Tandra Ráhim Khán, west of Sehwán. The principal localities for fossils are near the Gáj, where mammalian remains were first found by Vicary, and whence Mr. Fedden obtained several good specimens in 1876. Bones have also been found more recently on both sides of the Laki range, south of Sehwán.

It has already been mentioned that an estuarine bed is found at one place some 300 or 400 feet above the base of the Manchhars. This is near the Nari Nai, north-west of Sehwán. In lower Sind, and especially near Karáchi, marine or estuarine bands containing oysters and other shells become of frequent occurrence in the Manchhar beds, and some of these bands contain Gáj fossils; so that there is to the southward the same transition between Nari and Gáj which has already been shown to take place between all the other tertiary groups. It is clear that the lower Manchhars are of the same age as the Gáj beds, and if, as appears certain, the latter are Miocene, the lower Manchhars may be considered as upper Miocene.

This view is in accordance with the fauna, which includes only three living genera, *Rhinoceros*, *Sus*, and *Manis*; the generic identification in the last case is doubtful, being founded on a single phalange, and both the other forms existed in Miocene times. Besides these, *Amphicyon*, *Anthracotherium*, *Hyopotamus*, *Hyotherium*, some new genera related to *Merycopotamus*, and *Dinotherium*, are found in the Manchhar beds, but not in the Siwaliks, whilst the living types, *Semnopithecus*, *Macacus*, *Felis*, *Hyæna*, *Ursus*, *Cervus*, *Bos*, *Capra*, *Camelus*, *Camelopardalis*, *Equus*, *Elephas*, &c., which abound in the Siwaliks, have not been found in the Manchhar beds, so that, although several species, such as *Rhinoceros palæindicus*, *Acerotherium perimense*, *Chalicotherium sivalense*, *Sus hysudricus*, and two species of *Mastodon*, are common to the two, the presence of the much larger number of extinct forms, most of which are typically miocene in Europe, and the paucity of living genera, stamps the Manchhar fauna as of earlier date than the Siwalik.

Now, the Manchhar fauna, as has just been shown, occurs in the lowest Manchhar beds, whilst the Siwalik species are from the upper portion of the group. It is therefore far from improbable that the upper Manchhars represent the Siwaliks. The lower Manchhars may represent the Náhans of the Sub-Himalayas, or some of the lower portions of the Siwaliks themselves. The great distinction between the Manchhar and Siwalik fauna supports Mr. Lydekker's opinion, that the latter is of Pliocene age.

Nothing more has unfortunately been determined as to the relations between the Manchhar and Makrán groups. The former has not been traced to the west of Cape Monze, near Karáchi; at least no such rock could be detected during a traverse of the coast as far as Sonmiáni made for the purpose of endeavouring to trace the connexion between the two formations. The Makrán group, on the other hand, appears not to extend much to the eastward of Hingláj, so that there is a break between the two of the whole breadth of Sonmiáni bay—60 or 70 miles at least. Some of the Manchhar beds near Karáchi closely resemble certain strata in the Makrán group, but the typical whitish marls of the latter have not been noticed in Sind.

General sequence of tertiary beds in Sind.—We have thus in Sind a great sequence of later mesozoic and tertiary rocks, in which, despite the evidence of great changes in the conditions under which they were deposited, and despite local unconformities, there is no proof of any general break in the sequence throughout the province. In some places, as in the Laki hills, where upper Miocene Manchhars rest unconformably upon middle Eocene Khirthars, there is no question that elevation, and in all probability denudation, took place in the interval between the two formations, but elsewhere, as to the westward in the Habb valley, and to the northward on the flanks of the Khirthar, the break which exists in the Laki hills is represented by an uninterrupted sequence of the Nari and Gáj groups. At the close of the tertiary period, however, there is a great break, and the latest Manchhar (Pliocene) conglomerates are as constantly turned on end along the edge of the Indus alluvium as the very similar Siwalik conglomerates are in the Punjab.

The lower portion of the Ranikot beds, the upper Naris, and the Manchhars must have been deposited near land, for they contain terrestrial organisms, and all are probably fluviatile deposits; whilst the upper Ranikot, Khirthar, lower Nari and Gáj beds are clearly marine. Of all the marine beds, the Khirthar nummulitic limestone is the most important, and it is, as a rule, remarkably free from admixture of sand or other indications of the neighbourhood of land, but, as has been shown, this limestone is intercalated with sandstones and shales in lower Sind, and it entirely disappears in the south-western part of the province near the Habb river. The Gáj beds, on the other hand, are interstratified with sandstones and shales in the northern part of the province, but have a much more distinctly marine aspect to the southward, where limestones prevail. It is premature to reason broadly as to the changes in the distribution of land and water during the tertiary period until the rocks of Baluchistan are better known; all that can be done now is to point out the leading facts connected with the evidence afforded by the rocks in Sind itself; but it is impossible to avoid calling attention to the much greater prevalence of marine conditions during later Eocene and Miocene times in Sind than in the Punjab area to the northward, where no marine beds of later date than the nummulitic limestone have hitherto been detected.

ON THE ORIGIN OF THE KUMAUN LAKES BY V. BALL, M.A., F.G.S., *Geological Survey of India.*

In so far as the outer and lower ranges of the Himalayas are concerned, the group or series of lakes described in the following pages is in several respects quite unique.

To many out of the thousands who have visited the beautiful part of the country where these lakes are situated, the question of their origin must have presented itself. Doubtless, it is in consequence of the difficulties which surround the subject, that no one has ventured to publish his observations and deductions in full.

To Mr. H. F. Blanford, I believe, belongs the credit of having first[1] suggested in print[2] an origin for them. But the subject has often been discussed, and three or four years ago it was specially commended to my notice by one who has frequently visited Naini Tal, and whose acquaintance with the Alps and the literature of the subject led him to suspect that that lake might possibly have been excavated by an ancient glacier.

Could I foresee within the next few years any prospect of my being able to carry on my examination of the ground, I should not have presented this unfinished sketch; but as I do not do so, I think the publication of the facts here given desirable, as it may facilitate the speedy final solution of the question, and may also have the advantage of eliciting the opinions of experienced glacialists, who are unable to visit the locality for themselves.

During a recent visit to Naini Tal, I had hoped to have been able to have prepared a detailed geological map of the neighbourhood of the lakes, but circumstances beyond my control arose, which diminished my time for exploration by two-thirds. Though the area is not extensive, the complex and disturbed nature of the beds renders their true appreciation and demarcation a by no means easy task. Owing to landslips, and the fact of so large a portion of the basin of Naini Tal being built over, the accurate mapping of individual beds and of the trap will require much time to accomplish.

Of the age of the unfossiliferous metamorphosed schists in which the lakes occur nothing is certainly known. In the account of the Geology of Kumaun and Garhwal by Mr. H. B. Medlicott[3] will be found such information as exists on the subject. Some casual observations on the geology which bear upon the physical origin of the lakes will be found in their places below; otherwise there is no intention of giving a detailed account of the stratigraphy in this paper. Besides the map on the scale of one inch to a mile, shewing the relative positions of all the lakes, it has been considered advisable to give with this paper a copy of the large scale map of Naini Tal, which indicates very beautifully and with extreme fidelity the physical structure of the neighbourhood.

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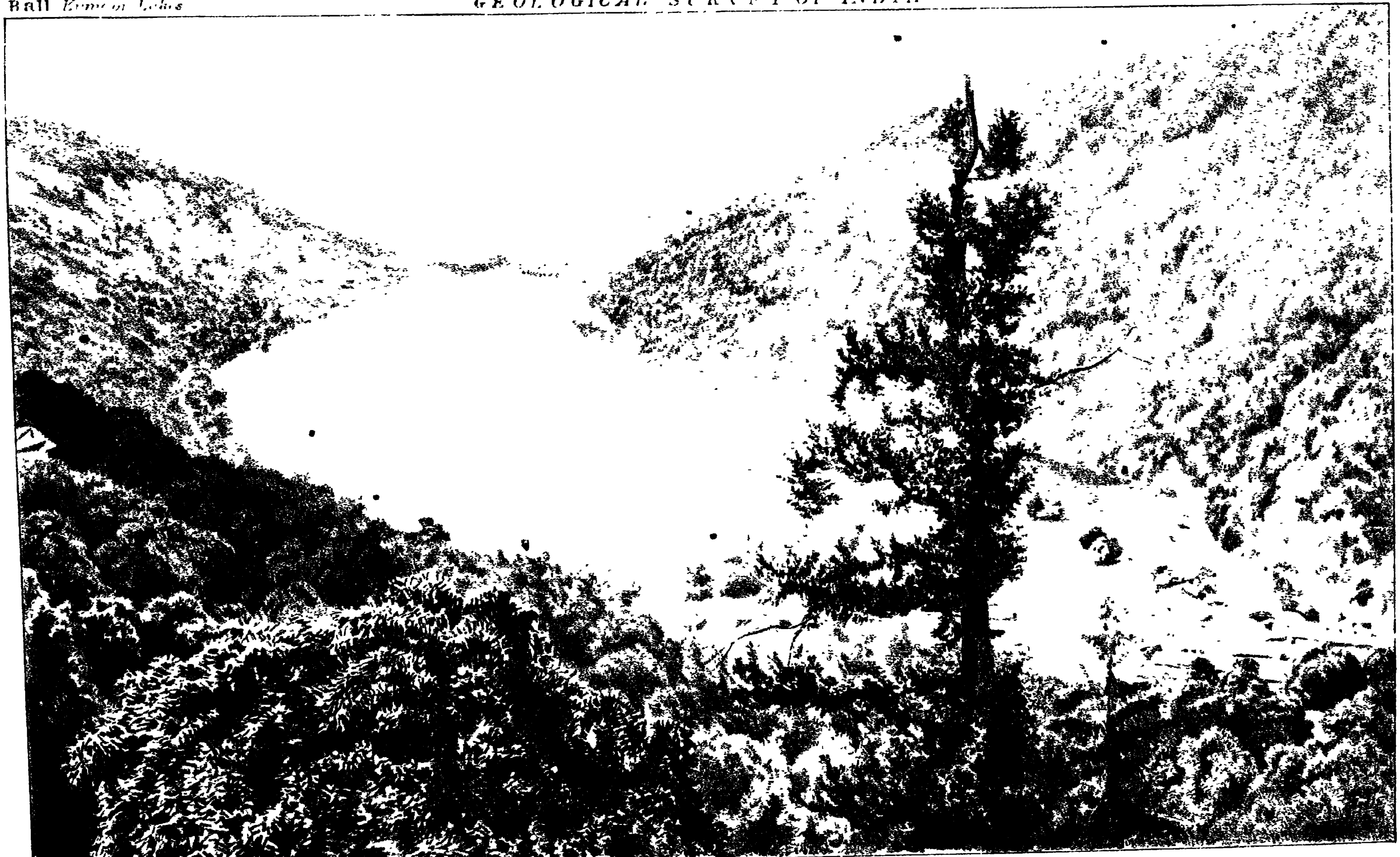
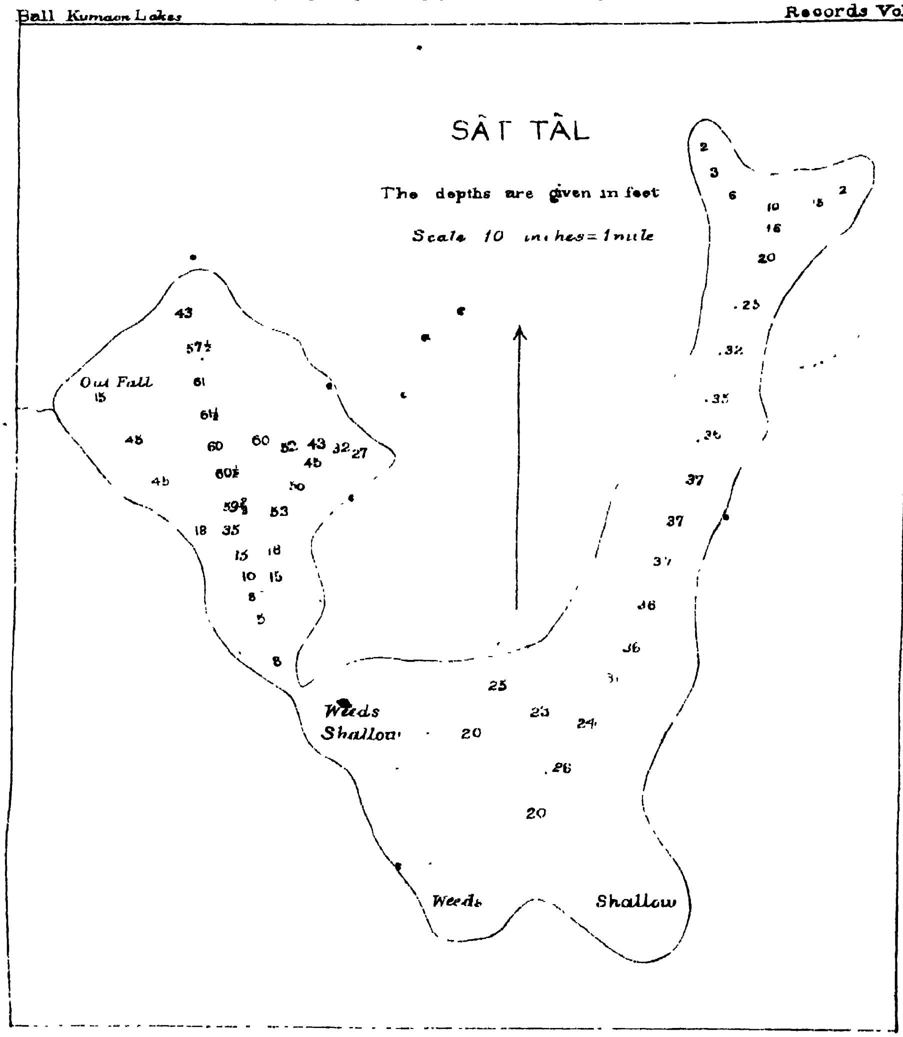
[1] Unless General Strachey's remark, that an outburst of amygdaloidal trap "is associated with the formation of several small lakes," is intended to be read as implying cause and effect.—Quar. Jour., Geol. Soc., Vol. VII, p. 298.

[2] Proc. As. Soc., Bengal, January 1877, p. 3.

[3] *Vide* N.-W. Provinces Gazetteer, edited by E. Atkinson, Esq., C.S.




SÂT TÂL
The depths are given in feet
Scale 10 inches = 1 mile
Out Fall
Weeds
Shallow
Weeds
Shallow

This series of *Tals* or lakes is included in the Chhakata pargana of Kumàun.[1] They are by no means all of equal size or importance. They seem, however, to fall naturally into three classes, the members of each class having certain features mutually in common. So arranged, they would stand as follows:—

Class I.—Naini, Bhim, Malwa.
„ II.—Naukachia, Sat.
„ III.—Kurpa, Dhobie, Saria, Sukha, Khoorea, &c.

NAINI TAL.—This lake, so called after a Hindu goddess, is situated about 10 miles in from the southern slope of the hills. It lies at the bottom of a valley, which runs about north-west south-east, and is surrounded on all sides, except at the outfall on the south-east, by lofty ridges, which serve to give an unusual amount of definition to the limits of the catchment area.

The greatest length of the lake itself is 4,703 feet, the maximum breadth 1,518 feet,[2] and the elevation of the surface at high water about 6,409 feet above the sea. The principal peaks on the encircling ridges are Luria Kanta, 8,144 feet; Sher-ki-danda; Ulma; China, 8,568[3]; Deopathar, 7,989; Iarpathar, 7,721.

The China (Cheena) portion of the ridge at the head or north-west end of the valley is steeply scarped above, with an undercliff much concealed by talus brought down by landslips. It consists chiefly of shales, with which there are some quartzites, and, towards the crest, there are limestones, which, so far as is clearly seen, may partake either of the nature of beds or veins. Passing hence round by north to south-east the ridge is mainly formed of shales and argillaceous schists, which are much contorted and broken; but the prevailing dip is probably to south-west, the beds striking with the direction of the ridge. An obscurely seen trap-dyke seems to observe the same course. To these two facts, the dip of the beds and the existence of the rigid trap axis, the present form of the slope is, I believe, under the influence of subaërial denudation, to be attributed; and not to the "friction of a glacier," as has been suggested by Mr. H. Blanford (*l. c.*).

It is true that there are no "subordinate ridges and spurs," but such is not uncommonly found to be the case where valleys run with the strike between hard beds bounding softer ones, which have been eroded to form the valleys.

Towards the end of the ridge, overhanging the Depôt, limestones, which are clearly seen in section to occur as irregular lenticular masses, not as beds, become somewhat abundant. I shall have to refer to them again presently. The range, on the south-west of the valley of which Iarpathar and Deopathar are the culminating peaks, is formed of massive limestones, the bedding of which is generally very obscure. There is also some trap, the combined rocks giving a very rigid and steep outline to the range, which contrasts most strikingly with that on the north.

[1] Excepting Malwa Tal, which is just outside the boundary.

[2] These figures are taken from a small table in the N.-W. Provinces Gazetteer, Article "Kumaun."

[3] The highest point is somewhat in excess of this elevation, which is that of the peak nearest to the lake.

All the rocks of this basin, whether shales or limestones, are singularly unsuited to the retention of the minor glacial marks; and if glaciation did take place, it may be from this cause that no such traces are now found.

From an inspection of the large scale map, it will be at once apparent that the head of the valley has very much the form of a 'cirque,' as defined by Mr. Helland,[1] who argues with considerable force that the cirques of Norway and Greenland are due to glaciers. Mr. Bonney,[2] on the other hand, describes Alpine cirques, which he believes to be formed by streamlets pouring down the sides. It has often been remarked how some forms of our Indian alluvia under the operation of heavy rainfalls exhibit in miniature many of the forms of denudation and erosion. Among these forms, cirques and cirque valleys are not unfrequently met with. Invariably, they are due not to denuding action from above, but to subterranean springs or streams. To a similar cause may, I think, be attributed cirque-like valleys in rocks formed of loose shales and, to some extent, even those where the rocks are limestones.

The accompanying section of the bed of the lake indicates a state of things very different from what might have perhaps been anticipated, but, however the lake has been formed, explanations to account for the peculiarity about to be described can be suggested.

The soundings from which this section has been plotted have been taken from the Revenue Survey map on the scale of ten inches to a mile. In some cases the exact character of the bottom is given, but not in all. A knowledge of this character is, no doubt, a very great desideratum for the discussion of this question. It would be especially desirable to know the nature of the bottom all across the lake transversely to this line at the point where the shallowest sounding occurs. As represented in the section, the lake consists of two basins, with the maximum depth nearly centrically situated in each case. They are separated by what appears to be a barrier. If it really be so, then it would lend considerable support to the glacial hypothesis. Indeed, if consisting of rock *in situ*, it would fairly prove the existence of a true rock basin, thus furnishing a strong argument in favor of the glacial origin. Supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier. Unfortunately the case is not susceptible of so simple an explanation, as the shallow sounding may be caused, not by a barrier, but by a mere hummock, which, if (as is possible, so far as is certainly known at present) occurring isolated by deep channels from the margins of the lake, would be on the other hand a strong argument against the glacial origin, as such an obstruction must assuredly have been swept away by a glacier capable of scooping out the deeper hollows. Still another view of the nature of the barrier or hummock, be it which it may, is possible. It may be that it is not really formed of rock *in situ*, but is merely the remnant of an ancient landslip.

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[1] "Cirques are large spaces excavated from the solid rock, bounded on three sides by an almost semicylindrical steep mountain wall, and with a tolerably flat floor."—Quar. Jour., Geol. Soc., Vol. XXXIII, p. 161.

[2] In making these remarks, I labour under the disadvantage of being in camp, away from opportunities of reference to Mr. Bonney's papers.

In the present state of our knowledge, therefore, no certain conclusion can be drawn from it. But the peculiar character of the basin still remains a subject for some speculation, the more particularly so when it is remembered that the operations of the present day must tend steadily to obliterate these features by the deposition of silt in the hollows.

Passing from the lake itself to examine the nature of the barrier at the outfall, we find that it is formed of a confused mass of debris, in which some very large rock masses, some of them ten feet in diameter, occur. Following down the bed of the stream, rock *in situ* is not met with till near the waterfall, or at a level which must be considerably below that of the bottom of the lake where deepest. I had neither the time nor means for actually ascertaining the elevation of the exact point where rock *in situ* is first met with in the stream. But it is an important point to be determined. The result would, I feel confident, completely dispose of any belief in the existence of a rock basin.

Mr. Blanford (*l. c.*), though he does not expressly state his belief that the large blocks of stone are erratics, suggests that they may be derived from the limestone at the ridge at the head of the valley (Deopathar). He states that his "impression was that the lake was closed by a morraine." The source of these blocks I believe to be much closer at hand. In great part they have, I think, simply tumbled down from the Iarpathar ridge and its eastern prolongation, where not only is similar rock to be seen *in situ*, but similar detached blocks are found on the slopes; one remarkably fine example being seen in the compound of Welham house. Others, on the other hand, may have fallen from the ridge to the north of the depôt, where the already described lenticular masses of limestone occur. The remainder may, I think, have simply been eroded from their envelopment of shales at, or very close to, the positions where they are now found. Though it is convenient to speak here of these blocks collectively as limestones, they vary much in character, and some are highly indurated, but only slightly calcareous, mud stones. From these varying characters it may be possible, hereafter, to trace their origin individually with considerable accuracy. As to the other characters of the debris at the outfall, I in vain searched in it for evidence of a glacial origin, and am unable to point to any feature which is inconsistent with the idea of its having been formed by a landslip.

Further down the valley, near Joli, some 3,000 feet or so below Naini Tal, I observed, when on the road to Ranibagh, that the river has cut through an accumulation of boulders and finer debris to a depth of 200 feet or so, which at the time seemed to me as possibly of morraine origin. On reading Mr. Campbell's opinion of the same kind of deposit near Kalka, which I have also seen, I fear it would require stronger facts than I am in possession of to prove it other than diluvial. I merely mention it here in order to draw attention to the fact of its existence, with a view to its future examination.

BHIM[1] TAL.—This lake is situated about 6 miles, in a direct line, to the east-south-east of Naini Tal. Its elevation is about 4,500 feet above the sea, or 1,900 feet lower than Naini Tal. It lies at the bottom of a valley between two ranges, which strike from north-west to south-east. The northern one is largely

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[1] So called after Bhim, Shib or Mahadeo, to whom there is a temple.

made up of greenstone, which I traced from the neighbourhood of Bhuwali, through Bhim Tal, up to Malwa Tal. According to General Strachey's geological map, a continuation of the same outburst extends northwards up to Bhujan on the Kosi. The southern range consists chiefly of quartzites and shales, and rises to a height of 1,300 feet above the lake.

At the entrance to the lake, in the very throat of the gorge, occurs a small hill, about 80 or 100 feet high, which deflects the in-flowing stream, and the existence of which, if it really is, as it appears to be, a stable prolongation of a spur, presents a serious obstacle in the way of a glacial theory. No one can deny, I think, that a glacier capable of scooping out the lake could not have passed over, or on one side of, such an obstruction.

The determination of the fact, whether this hill consists, and to what extent, of rocks *in situ*, is a point, I believe, of crucial importance in this enquiry. Bearing in mind the vast size of the landslips which take place in this region, no one should hastily venture an opinion on such a point. My examination of the ground was of too cursory a nature to admit of my coming to a final decision.

The maximum dimensions of this lake are, length 5,580 feet, breadth 1,490 feet, and depth 87 feet. It is, therefore, the largest, but the shallowest,[1] of all the series herein described.

Whether it be a historical fact or not I cannot say; but it is clearly, I think, *a fact* that the present outlet of the lake was not the original one. The waters now only escape through a sluice close to the temple, which is situated about midway on the eastern side; but that originally the water found its way out at the southern end, an inspection of the map alone is almost sufficient to determine.

This southern end is now stopped up by what appears to be the debris of a landslip. I was unable to examine the valley below, and the position and elevation of the highest rocks there remain to be determined. At the present outfall, the rocks *in situ* are apparently at a higher level than the bottom of the lake; but this, if it be the case, is a fact of no importance, if my supposition as to the position of the original outfall be correct.

Towards the southern end of the lake, on the eastern side, there is a boulder deposit, which extends along the bank up to a level of perhaps 10 feet above the water. The rounded blocks which it includes were possibly rounded by the waters of the lake when they stood at a higher level, but its appearance suggests a morraine origin. The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslip, the materials must have come from the west, and, of necessity, temporarily filled up a portion of the bed of the lake. As elsewhere, my examination here was very hurried, and I therefore commend this deposit to the notice of future visitors.

MALWA TAL.—This lake is situated about five miles, in a direct line, to the east of Bhim Tal; it lies in a deep valley, which strikes north-west and south-east, and is traversed by the Kalsa river, a tributary of the Gola.[2]

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[1] Sat-tal being excepted as regards depth.

[2] It is perhaps worthy of note that the drainage of all these lakes is into the Gola river.

The elevations of the parallel bounding ranges on the north-east and south-west average upwards of 3,000 feet above the level of the lake, the height of which above the sea has been approximately estimated at 3,400 feet.

The range on the north is formed chiefly of white and purple quartzites, with which there are some slates and shales. The dip of these beds is variable, but north-west at a low angle seems to be the prevailing direction. Much of the higher face of this range is steeply scarped, but landslips abound, and have, to a great extent, concealed the character of the lower portions.

The range on the south consists primarily of an axis of greenstone, which stretches continuously hence from the neighbourhood of Bhim Tal. Associated with this greenstone are quartzites and shales, the beds in immediate contact often showing signs of much alteration and induration. Occasionally the effect of the former has been such as to cause the affected beds to assimilate to the characters of the greenstone, and to be almost inseparable from it, by mere examination of their outward lithological structure.

What the exact nature of the physical relations of this greenstone may be, has not yet been fully ascertained; but that it does not exist merely as a single simple dyke is amply testified by the fact that branches from it cross the valley at both ends of the lake, and are cut through by the infalling and outfalling streams.

At the head of the lake is a boulder bed through which the river cuts to a depth of eight or ten feet. This deposit consists chiefly of subangular fragments of trap and quartzite. At first I was inclined to attribute it to the effects of a retreating morraine. Temporarily this view was supported by the discovery of boulders of granite and gneiss—no *known* source for which exists within the present drainage limits of the Kalsa. It was impossible, however, to overlook the fact that there were no signs of polishing on any of the blocks, and that those which have come furthest (the granite, &c.) are well rounded and water-worn. Taking into consideration the professedly general character of the only existing geological map, it would be clearly unsafe to adopt the view that no source for these boulders exists within the watershed; and this the more especially as in the adjoining basin of the Gola on the north the occurrence of gneiss and granite is indicated on the map.

The importance of determining the source from whence these boulders have been derived is sufficiently obvious. If they have not come from within the limits of this catchment basin, then indeed it might be necessary to invoke the aid of an ice cap to account for their transport; but in the meantime it is impossible to assert that this accumulation of boulders at the mouth of the gorge is other than a delta of diluvial origin.

Now as to the character of the lake itself. Its maximum dimensions are, length 4,480 feet, width 1,833 feet, and depth 127 feet. Unfortunately, as was the case with Bhim Tal, no series of soundings are available, and the form of the basin is, therefore, uncertain. The bounding ranges and their slopes, however, indicate the **V** (river) rather than the **U** (glacial) type of valley denudation.

Looking up the lake towards the course of the stream, the view just beyond the gorge is quite shut out by projecting spurs, which a glacier could have scarcely failed to modify, if not remove.

At the outfall, no rocks are seen *in situ*. The barrier, now modified by a sluice, appears to be mainly formed of debris thrown down by landslips. The first rock which I detected *in situ* in the bed of the stream was the already mentioned greenstone, which will, I believe, prove to be at a lower level than the bottom of the lake.

As I only had a single day to spend at this lake, I was unable to examine the characters of the wide and unusually straight valley below the village of Malwa Tal (*vide* map); its examination may throw some light on the subject.

NAUKACHIA TAL.—This curiously irregular-shaped lake has received its name from its nine corners. It is situated about one mile and a half to the south-east of Bhim Tal. It occupies a hollow on the slope, and is surrounded by low hillocks, not by pairs of distinct ranges, as are the previously described lakes.

With a very narrow outfall on the north-west, its appearance, as seen from a mile distant, suggested its being little more than a shallow pond. And it did not seem to me to be advisable to curtail my already too short time at the other lakes by paying it a special visit. On returning to Naini Tal, I found, very much to my astonishment, that its depth is recorded at 132 feet, thus being the deepest of the series. If this be the correct depth, it renders the lake one of the most singular of all. Its shape, the nature of its surroundings, and the narrow winding course of the outfall, all seem inconsistent with the view that it is of glacial origin.

Its length is given at 3,120 feet, its breadth 2,270 feet, and its approximate elevation above the sea 4,000 feet.

SAT TAL.—The so-called Sat Tal, or seven lakes, are situated about the same distance to the west of Bhim Tal that Naukachia is to the south-east. They are surrounded on all sides by steep hills, a narrow valley, 100 yards wide, at the outfall of the principal lake serving to carry off the drainage. What the maximum depth may be, I do not know; but two soundings, which I took in the western arm of the principal lake, gave depths of about 58 feet. The artificial dam and sluice somewhat increases this depth over what it would be naturally.

At the outfall there is a landslip, and I do not think any rocks are seen *in situ* till a much lower elevation is reached than 58 feet below water-level.

It is scarcely probable that this group of the seven lakes was in any way formed by glaciers. I have seen in parts of the Central Provinces, where no question of glaciers can arise, denuded hollows among hills, which, if closed by landslips, would form very similar lakes.

Since writing the above, I have received from Mr. Yule, of Bhim Tal, the accompanying plan of soundings, which he has kindly taken in the principal of the Sat Tal at my request.

When it is remembered that this curiously shaped lake has but one narrow outlet, and that it is otherwise surrounded on all sides by hills, but without any considerable catchment area for a glacier to be formed and fed, the difficulty in the way of a glacial theory of origin becomes strikingly apparent.

The maximum depth, it will be seen, is given by Mr. Yule as $61\frac{1}{2}$ feet, so that I must have failed to hit off the deepest part.

Of the smaller lakes enumerated above under class III, I have nothing to say at present. They have not yet been specially examined. Very possibly, there may be in connection with them various points of interest to be yet discovered.

CONCLUSIONS.—Reviewing the whole of the facts which are enumerated above in reference to each of the lakes, and considering the limited zone in which they occur—the probability that they are all the result of one general series of operations impresses itself as being an hypothesis of primary importance. If one of the lakes then exhibits indications which seem to connect it with one particular mode of origin, while others of the lakes do not show such or similar indications, it becomes all-important to submit the former to the severest scrutiny. In this way, I think, the appearances suggestive of a glacial origin, which are perhaps strongest in the case of Naini Tal, lose much of their force when we find that other lakes exist of generally similar character, but in which the special indications are wanting. In the single character of the outfall barriers all the lakes agree; opinions may differ as to the origin of these barriers, whether they are remnants of morraines, or have been formed by landslips; but it is almost certain[1] that not one of them consists in any degree of rock *in situ*, and we therefore have not the positive aid of a rock basin to determine a conclusion.

There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each. Now, I do not think it at all probable that the lakes are due to the original outburst of trap. Indeed, the above described fact in reference to Malwa Tal, where both the inflowing and outflowing streams cut through trap, renders such a view untenable. But it seems not improbable that, when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c., may have been so much crushed and broken, as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of material for landslips, which ultimately served to close the valleys, and form the lakes.[2] Or even supposing the outburst of trap to have accompanied the upheaval and disturbance, its effect in determining the subsequently established lines of denudation could not fail to make itself felt.

This explanation, in part suggested by Mr. Medlicott's observations in his well known paper on the Alps and Himalayas,[3] seems to me more in accordance with the known facts regarding the whole series of lakes, than any glacial theory can be.

[1] Careful levelling can only decide this point.

[2] It is possible that the basin of Naini Tal may be connected with some local faulting, the existence of which is implied by the sulphur spring at the outfall. That a fault occurs all along the centre of the valley is, however, scarcely probable, as, did one exist, it would show in the scarp of China, the beds forming which appear to be continuous across the head of the valley.

[3] Quar. Jour., Geol. Soc., February 1868.

Before commencing examination, I was myself inclined to believe in the probability of a glacial origin; but as my observations have accumulated, I have been constrained to adopt the view, that the balance of evidence available at present is against such an explanation. At the same time, I have indicated that there still remain several points for determination, which are of almost crucial importance. Future observers will, probably, give a large portion of their attention to some of these questions, and, with the aid of the maps, soundings, &c., here given, will be able to add considerably to the above data, thus affording fuller material, by which it is to be hoped a sound and stable conclusion may be finally arrived at.

I have only to add that it appears unadvisable at present to refer particularly here to the debated question, as to the evidence of the former existence of glaciers at low elevations in Kangra and elsewhere.

For the present, the two series of observations had best, perhaps, be kept quite separate, but their ultimate connection and relationship is, of course, none the less obvious.

NOTE ON A TRIP OVER THE MILAM PASS, KUMAON, BY THEODORE W. H. HUGHES, A.R.S.M. F.G.S., *Geological Survey of India, with a* DESCRIPTION OF THE FOSSILS BY DR. WAAGEN, *formerly Palæontologist to the Survey.*

Early in August 1873, an opportunity being afforded to spend a few weeks in Tibet and the higher regions of the Himalayas, my colleague, Mr. Hacket, and I undertook to strike across from Álmóra to Milam, and return by the Niti pass. I had once before, in 1869, been through the Milam pass, but I was so distressed by constant pains when at high elevations, that I made no observations worth recording. A judicious preparatory training enabled me on the present occasion to enter the lists, and fight with fair success, against the trials of high-region travelling, and my note-book was brought more into requisition.

The time of year at which we started was too unfavourable to make any other than road-side observations among the lower hills. We were in almost constant rain during our first ten marches, and, however enthusiastic our aspirations in the cause of geology at the outset of each day's journey were, they could not withstand the depressing effect of recurring downpours of water, and we hurried to shelter as the most prudent course to pursue. It was not until we reached the Bhótia village of Rilkót, that we passed out of the region of rain.

We were fortunate enough to secure a small collection of organic remains, which, on examination by Dr. Waagen, afforded evidence of the presence of several formations not hitherto detected in this region, and bringing the section here more into correspondence with the sequence of fossiliferous strata established by Dr. Stoliczka in the North-Western Himalayas. To this extent our trip was a satisfactory one; we failed, in that we made no attempt to fix accurately any geological boundaries.

It is easy, however, to reduce within narrow limits the debatable border-land of the fossiliferous and non-fossiliferous rocks, and certain localities can be

referred to their true palæozoic horizon. The main interest of this paper is embodied in Dr. Waagen's remarks; so, after a brief account of the azoic region from Álmóra northward, I will quote them in full, adding a few comments of my own.

We left Álmóra on the afternoon of the 3rd August, and encamped for the evening at Tákli, and on the following day got into Bágéswar, a distance of 30 miles from Álmóra.

Tákli; Bágéswar.

The rocks traversed belonged to the metamorphic series, and consisted of quartzites and schists, a few slate bands and some limestones, with a general dip to the north. Good slates occur in the rise of the hill near Billári, and capping the hill is a great mass of limestone.

Slates.

Where the road slopes to the Sarju river, about four miles south of Bágéswar, soapstone appears. It cannot fail to be noticed in the "rains," from the circumstance that at every step you take down the hill, your feet slip from under you, unless great care be exercised.

Soapstone.

Between Bágéswar and Kapkót—the next halting-place, 12 miles distant—similar rocks to those already passed over occur. An impure bed of graphite crops out in the left bank of the first tributary of the Sarju beyond Bágéswar, where the roadway is carried over on a wooden bridge.

Kapkót.

Graphite.

From Kapkót we went on to Sháma, a distance of 13 miles. The road leaves the valley of the Sarju at its junction with the Réhra, and follows the course of the latter river. The rocks are of the same character as those seen during the past marches, and have still their northerly dip. Deposits of recent limestone are very prevalent; and at Khar-baggar, where the road to the Pindra glacier leaves the one we were travelling, there is a sulphureous spring.

Sháma.

Our march to Tézam was only 7 miles, but a great deal of climbing had to be done, and we did not arrive until the afternoon. In addition to the ordinary quartzites and schists, and superficial deposits of calcareous tufa which were very numerous, there is a considerable thickness of white dolomitic limestones, compact and very fine-grained. A splendid cliff-section of them occurs at the mouth of the Jánkúli river, which falls into the Rámganga, opposite Tézam. Another short journey of 4½ miles brought us to Girgaon, situated high up a hillside. For the first 5 miles the road runs along the right bank of the Jánkúli, and more dolomite is exposed. Near Girgaon talcose quartz-schists replace it.

Tézam.

Dolomitic limestone.

Girgaon.

To Múnshiari,[1] our next halting-place, was 8 miles. The route was a very trying one, owing to the number of heavy ascents and descents. For some way beyond Girgaon the most pro-

Múnshiari.

[1] Múnshiari is not the name of a village, but the term applied to the whole of the villages that are clustered around Jallat and Súring.

minent rocks are the talcose quartz-schists; but, beyond the ordinary breakfasting place, the name of which I have forgotten, highly garnetiferous micaceous schists are common, and garnets may be picked up in hundreds in little depressions and amongst the roots of trees and shrubs.

We halted one day at Múnshiari, in order to pay a visit to the localities whence are obtained the ovoid stalactites, sold as curiosities to travellers by the people of Múnshiari. The guide took me down to the Góri river, and pointed to places in the cliffs forming the banks, and said they were found there; but I failed to procure any, and I question very much whether I was shown the right spots.

Change in character of rocks.

Lélam.

In the neighbourhood of Múnshiari we began to notice a change in the character of the rocks; and on our next march to Lélam we saw some typical gneiss between Dalkót and Tala Dúmár; dip north, at 25°. Opposite Tala Dúmár black mica-schists, in some instances highly garnetiferous, and hornblende schists occur above the gneiss.

Bághdúar; Rilkót.

Central gneiss.

From Lélam we marched to Bághdúar, and thence to Rilkót. The road keeps in the valley of the Góriganga, and a magnificent section is exposed of what Dr. Stoliczka terms his central gneiss.[1] It is traversed by granite veins, in the manner described by him.

Búrfú.

Still keeping to the valley of the Góriganga, our next halting-place was Búrfú, where we were forced to remain several days until a sufficient number of jabbús (half-bred yaks) had been collected to carry our camp stores and equipage. Búrfú is beyond the ground of the central gneiss, and the rocks between it and Rilkót are quartzites, slates, and schists. Near Tola I noticed an immense number of crystals of iron pyrites in almost all the beds that I examined.

First fossil found near Shilong.

Our first discovery of a fossil was beyond the village of Milam, near Shilong, one of the halting-places of the Bhótias, in some fine silicious sandstone. I think that the *Strophomena aranea*, Salter, which is the only silurian form in our collection, is the specimen referred to; but I am not quite sure, the label having been lost. Along the remainder of our route to the snowy passes, and especially at the foot of Únta Dhúra, we made several additions to our bag of fossils; and each day's journey to the frontier, and through Tibet, enabled us to increase our stock.

Dr. Waagen says of our collection:

Cretaceous fossils.

"The fossils brought by Mr. Hughes from the Milam pass can be attributed to at least five formations, which are indicated with more or less certainty by the different species. I consider as very probably of cretaceous age some pieces of a flaggy yellowish grey limestone, filled with fragments of shells intermixed with entire specimens, which,

[1] Memoirs, Geol. Surv., India, 1866, vol. V, page 12.

though the species could not be determined, yet, by the association of the genera, indicate with great probability the cretaceous formation. I worked out of those rock specimens—

"*Corbula*, sp., allied to, perhaps identical with, *C. cancellifera*, Stol.; as, however, only one specimen has been found, the determination could not be made with sufficient certainty.

"*Astarte*, a middle-sized species, rather oblique in shape, with concentric folds near the apex, nearly smooth on the other parts of the shells; could not apparently be identified with any of the hitherto described species. This shell seems to fill whole beds with hundreds of specimens.

"*Pectunculus*, sp., a large, smooth, rounded shell, found among the *Astartes*. The species could not be determined, but the occurrence of this genus together with a true *Astarte* indicates nearly with certainty cretaceous beds.

"*Cucullaea*, sp., fragmentary.

"The jurassic formation is represented in the collection, by a tolerably large number of fossils, preserved much in the same way as those found in Spiti.

Jurassic fossils.

"I determined—

Belemnites cf. *kuntkotensis*, Waagen (fragments of the guard).
Oppelia acucincta, Strachey.
Perisphinctes frequens, Opp.
,, sp. (*triplicatus*, Stol. *non* Sow.)
,, *sabineanus*, Opp.
,, *stanleyi*, Opp.
,, sp.
Stephanoceras ? wallichii, Gray.
Cosmoceras theodori, Opp.
,, *octagonus*, Strachey.
Aucella leguminosa, Stol.
,, *blanfordiana*, Stol.
,, sp. *nov.*
Pecten, sp.
Rhynchonella, sp. (*varians*, Blanf. *non* Schloth.)

"The genus to which *Ammonites wallichi*, Gray, belongs is rather doubtful, as no sufficiently well-preserved specimen has been found to make this point certain. *Perisphinctes stanleyi*, Opp., is a very good species, and easy to distinguish from *Perisphinctes cautleyi* and *spitiensis*, with which it has been identified. The new *Aucella* is a large rounded shell, with very few concentric striæ, but it is represented only by a single specimen. Nevertheless I thought it worth mentioning; as the occurrence of a new (a third) species in the Himalayan Jura shows yet more clearly the intermixture of European and North Asiatic types in these jurassic districts. In Kachh already species of the genus *Aucella* are exceedingly scarce, whilst north of Milam some of the rocks are filled with hundreds of *Aucella leguminosa*."

Almost all the jurassic specimens just described are from the neighbourhood of Laptél. They occur mostly in concretions, in dark-looking slightly carbonaceous shales, that constitute the most distinctive rocks of the formation. At

Laptél the shales overlie limestones, and they form a trough, which has a north-north-west south-south-east strike. They extend southward as far as the halting-place at the foot of the Kíngrú ghát.

Triassic fossils.

"The different formations of the triassic period are very poorly represented in the collection, but nevertheless the materials are sufficient to state with all certainty the existence of these formations. To the upper Trias very probably belong some hard, flaggy, dark-grey limestones, with millions of fragmentary shells imbedded. However, only on the weather-worn surfaces some species can be recognised, it being impossible to get anything out of the interior of the rock. I am able to recognise one species of *Monotis*, and two species of *Pectens*, on three different rock specimens. The only species determinable, however, is *Rhynchonella austriaca*, Suess.

"There are yet two other divisions of the Trias indicated by fossils in two different kinds of rock. The one is represented by two fragments of Ammonites of the group of *Ammonites semipartitus*. They are preserved as black nodules in a hard, dark-grey, silky, slaty shale, which very likely belongs to the 'Muschelkalk' formation. The other division of the Trias is indicated by a small specimen of a badly preserved *Ceratite*, somewhat like some species of the Salt Range, and thus possibly out of some 'Bunter Sandstein' beds. The rock in which it is preserved is a hard, red, crypto-crystalline limestone.

"These few fossils, though badly preserved, and specifically not determinable, yet show beyond a doubt the existence of a rather complicated group of triassic rocks."

There are two geographical zones of this and the underlying series, one being south of Laptél, and the other north of it, in the direction of Kanchégo.

Permian and carboniferous fossils.

"The next older formations, permian and carboniferous, are represented in the collection by a somewhat better suite of fossils. The most fossiliferous bed is a white limestone with a great number of fragments of crinoid-stems, and the following determinable species:—

" *Terebratula himalayensis*, Dav.
" " *subvescicularis*, Dav.
" " sp. *nov.?*
" *Athyris roissyi*, L'Ev.
" *Spirifer* cf. *glaber*, Martin.
" *Camerophoria*, sp. *nov. ?*
" *Productus semireticulatus*, Martin
" " sp.
" *Bactrynium* sp.
" *Cyathophyllum* sp.

"It is very interesting to trace how much this fauna resembles that of the lower carboniferous limestone in the Salt Range; and even the preservation of the specimens is such, that they could be mistaken as coming from the Salt Range. *Productus semireticulatus* occurs of its typical size, whilst the small form from Spiti, which is found also here, and quoted by me as "*Productus*, sp.," is very likely a different species. The latter, however, has been also obtained, though rarely, from the Salt Range.

"The *Camerophoria* quoted above is a beautiful large species, which I could not determine for the present. The *Bactrynium* also is interesting, which is found plentifully in identical specimens in the Salt Range. The genus has been described by Gümbel after a very small species out of the 'Kössener' beds of the Bavarian Alps. The zoological relations of the genus, however, are as yet thoroughly unknown.

"Other beds, possibly also of carboniferous age, which, however, could not be ascertained by the few fossils obtained from them, have furnished:—

Rhynchonella, sp.

allied to *Rh. acuminata*, Martin, preserved in a black hard shale, and

Spirifer cf. *striatus*, Martin,
Stringocephalus ?? sp.
Rhynchonella ? sp.

all bad specimens, preserved in a dark liver-coloured limestone."

The dark-coloured limestone is very probably of carboniferous age, as it came from the same locality as the rocks which furnished the fossils of undoubted carboniferous affinities.

Silurian fossil.

"Of all the silurian formations, there is only one specimen of rock in the collection, consisting of a bit of white not very hard sandstone, with manganese specks, upon which several casts of *Strophomena aranea*, Salter, are observable."

The sandstone in which this brachiopod occurs comes, as well as I can remember, from the neighbourhood of Shilong, as already mentioned.

The following list of halting-places and distances from Álmóra to Milam may be useful:—

Name of halting-place.	Distance.	Remarks.
1. Tákli	16 Miles.	No resting-house.
2. Bágéswar	14 "	Dák bungalow.
3. Kapkót	12 "	Dharamsála.
4. Sháma	13 "	Ditto.
5. Tézam	7 "	School-house.
6. Girgaon	6½ "	No resting-house.
7. Múnshíari	8 "	Dharamsála.
8. Lólam Thánkót	6 "	Cave.
9. Bághdúar	8 "	No shelter.
10. Rilkót	8 "	Ditto.
11. Milam	8 "	Ditto.
TOTAL ...	106½ "	

THE MUD VOLCANOES OF RÁMRI AND CHEDUBA; *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

During a recent tour through Rámri and Cheduba, the main object of which was to examine and report on certain coal-beds said to exist in the islands, I had an opportunity of visiting the greater number of the mud volcanoes, the occurrence of which has long been known, and brief allusions to which are to be found in many standard works on volcanic phenomena and on general geology.

The original sources of information referred to in such works consist mainly of a "Report on the Island of Chedooba" by Commander E. P. Halsted,[1] which, amongst other matter, contains valuable and, with but few exceptions, accurate observations both on the volcanoes, and on the elevation of Cheduba and the neighbouring islands which has occurred within the last two centuries. Besides the above, a few notes on the volcanoes of Rámri may be found in Lieutenant Foley's Journal of a tour through that island, and in a paper on some coal which had recently been found at Kyauk Phyu.[2] Dr. Spry, also, has briefly alluded to one of the volcanoes near the last named place in his account of "A three weeks' sail in search of health."[3] Notices by Captain J. Russell of a volcanic island which rose from the sea near Cheduba in 1843 and subsequently disappeared; of a fire at sea witnessed from Kyauk Phyu in 1845, and conjectured to have been volcanic; and by Major Williams of an eruption from one of the Kyauk Phyu volcanoes in 1846, have also been published.[4] To all the above records I shall subsequently have occasion to refer.

The allusions to Rámri and Cheduba by systematic writers refer mainly to the fact of the mud volcanoes there being at, or near, the end of that great line of volcanic vents which may be traced thence southwards by Narkondám and Barren Islands, in the Bay of Bengal, through the entire length of Sumatra, Java, and the eastern islands of the Sunda group. By some, indeed, this line is considered only a portion of a still greater one which, stretching from Tierra del Fuego northwards, along the western fringe of South and North America, is continued through the Aleutian Islands, Kamschatka and Japan to the Phillipine and Molucca Islands. There it is considered to divide into two, one branch running south-east through Papua, the New Hebrides and New Zealand; the other passing, as before said, through Java and Sumatra, and having its furthest limit in Arrakán and Chittagong.[5]

[1] Journal As. Soc., Bengal, X, 1841, pp. 349, 419.

[2] *Ibid.*, II, 1833, p. 595; IV, 1835, p. 20.

[3] Journal As. Soc., Bengal, X, 1841, p. 138.

[4] *Ibid.*, XII, 1843, p. 1114; XIV, 1845, Proceedings for February; XV, 1846, Proceedings for November.

[5] Scrope on volcanoes, p. 12; Lyell's principles, 10th edition, II, p. 585. There is a 'true' volcano, called Puppá-doung, about 30 miles east of the Irrawádi, in latitude 21°, but it has been long extinct. It has been described by Mr. W. T. Blanford, who believes it to be of Miocene or Pliocene age, more probably the latter (Jour. As. Soc., Bengal, XXXI, 215).

Physical features of Rámri and Cheduba.

Orographically and geologically, however, the islands in question, which, with the islets in the neighbourhood, may be conveniently spoken of as the Rámri group, are intimately connected with the Arrakán range of mountains, which, running from Cape Negrais northwards towards Manipur, forms the dividing ridge between the basin of the Irrawádi and the smaller rivers of Pegu, Arrakán and Chittagong, which find their way direct into the Bay of Bengal. In the latitude of Rámri this range attains in places an elevation of from three to nearly five thousand feet, the hilly islands in question constituting outliers on the western flank of the range. Rámri is separated merely by a narrow creek from the mainland, to which the whole group would be connected by an elevation of a few fathoms.[1]

No map is in existence which correctly delineates the orographical features of these islands. The Rámri hills are disposed in very numerous, and generally irregular, ridges. In some cases, where bands of harder rock preserve a uniform dip and strike, as between Likmau and Minbain, straight and well defined ranges occur, but more frequently, owing to the irregularity of the strike and dip, and the softness of much of the rock, the hills are irregular in their direction and featureless in outline. There is, however, a general tendency to a direction approximating to north-west—south-east. Generally the rounded, jungle-clad ridges vary in height from one or two hundred feet to double or treble that elevation. The hills in the southern part of the island are, on the whole, higher than those further north. Lieutenant Foley estimated the height of Jika, a hill not far from the coast, to the south or south-south-west of the town of Rámri, at 3,000 feet, but this requires confirmation. The highest Revenue Survey Station on the island is about 700.

Between the various ridges, and stretching to either side of the tidal creeks by which the island is intersected, are alluvial flats which are often of large area, and taken together constitute an important proportion of the island. As an illustration of the extent to which the latter is penetrated by such creeks, it may be mentioned that, at high tide, boats of 10 or 12 fathoms length can go up the Minyát River to the village of the same name, which is within less than two miles of the western coast.

My acquaintance with Cheduba is confined to the eastern side. Captain Halsted, however, who surveyed the island, describes the general features thus: "Its general appearance and character is that of a fertile well-wooded island of moderate height, and irregular outline. A band of level plain, but little raised above the sea, extends around its coasts, of far greater width on the east than on the west; within this lie irregular, low, undulating hills, varying in height from 50 to 500 feet, enclosing several higher detached mounds of steep, well-wooded sides, the loftiest of which, near the south part of the island, rises nearly 1,400 feet."[2]

The larger of the outlying islands are very similar to the main ones, on a smaller scale; low rounded hills from 100 to perhaps 300 feet high rising from cultivated alluvial plains.

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[1] *Vide* Admiralty Chart of Bay of Bengal, 1876, sheet 4.

[2] On the map of the province of Pegu, scale 8 miles=1 inch, published in the Surveyor General's Office, 1856, a hill, presumably that alluded to by Captain Halsted, is marked 1,700 feet.

Recent elevation.

The evidences of recent elevation, visible along the coast in many parts of these islands, are patent at a glance. The southern portion of Round Island is occupied by a little rocky table-land 100 or 150 feet high, and the remainder by a plain elevated but a few feet above the sea. A portion of the latter is composed of rounded pebbles and boulders of rock, lumps of coral, sand and broken shells—a raised sea-beach. The remainder is an alluvial flat, formerly doubtless a mangrove swamp, but now occupied by rice-fields, amongst which are some large rocks with marine shells still adhering to them. At the northern end of the island there is a detached rock on the beach which strikingly illustrates the elevation, crowned, as it is, by an aggregated mass of marine shells, the base of which is about six feet above the present high tide level, and the upper surface covered with grass and shrubs (*vide* illustration). Rocks of a similar kind are also to be found elsewhere on Round Island, as well as on Regnain, or Flat Island, to the south. A map of the latter is appended to Captain Halsted's paper, showing the present island to consist of three terraces differing from each other in level by six or eight feet, *i. e.*, 1*st*, the original island (containing a mud volcano in its centre) previous to the elevation, which is said to have taken place about the middle of the 17th century; 2*nd*, the island after this occurrence; and 3*rd*, the present island, the outer portion of which was raised about the year 1750[1] according to native information obtained by Captain Halsted. The last elevation was accompanied by a very violent earthquake: in Cheduba "the sea washed to and fro several times with great fury, and then retired from the grounds, leaving an immense quantity of fish, the feasting on which is a favorite story throughout the island; no lives were lost, no rents in the earth occurred, nor fire from the volcanoes of the island." It has been suggested by Mr. Piddington (native villagers not being very accurate, generally, as to dates) that the earthquake was coincident with the submarine volcanic eruption described as having occurred off Pondicherry in 1757[2], and, with much more probability, by Lieutenant Baird Smith, to have been the same earthquake as that which partially destroyed Chittagong in April 1762, and which was felt throughout Bengal, Arrakán, and Pegu.[3] A comparison of Captain Halsted's map of Flat Island with the present shore line indicates no further elevation since the date of his paper.

His measurements show the total elevation to have been 9 feet at Foul Island, 50 miles south-east of Cheduba, from 12 to 22 feet in various parts of Cheduba itself, and 13 feet at the Terribles, west of Kyauk Phyu; the elevation having been greatest towards the north of Cheduba, and declining both to south-east and north-west. Evidences of the inequality of the elevation are also to be found in Rámri. On the western coast, between Konbaung and Kyauk Galé (and doubtless further) there is a raised beach about 20 feet above

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[1] Ninety years before 1841 according to the text, which refers to Cheduba. On the map of Flat Island the last elevation there is stated to have occurred eighty years before the same date, but this would appear to be a clerical error; there is no allusion in Captain Halsted's paper to a difference of ten years between the last elevations of Cheduba and Flat Island respectively.

[2] Trans. Bombay Geographical Society, X, 140. [3] Journ. As. Soc., Bengal, XII, 1050.

the sea, strewn over with worn lumps of coral, and of rock bored by *Pholadidæ*[1], whose shells still remain in the holes. But a large part of the alluvial area on the eastern side of the island, not more than a few feet above the sea, does not exhibit such evident signs of recent elevation, nor does there appear to be any tradition of such large proportion of the island having recently emerged.

The elevation at the Baránga Islands has been comparatively slight. In one place, however, at the north end, I observed oysters sticking to the rock about two feet above spring high water mark. Further north again, the effects of the great earthquake of 1762 were of a precisely opposite character, large areas in the Chittagong District having been then *submerged.*[2]

Geological character.

The rocks are of a very similar character throughout the islands, consisting almost entirely of shale and sandstone. The former is of different shades of gray; although sometimes well bedded, much more frequently it is clunchy, and not uncommonly passes into clay. Almost everywhere it includes numerous large irregular nodules, or short strangulated beds, which are more or less calcareous, and some of which are tolerably pure limestone. These nodules are often traversed by strings of calcspar. Irregular strangulated veins of the same mineral also intersect the shales themselves, in places, and the latter are occasionally gypseous, containing small disseminated crystals of selenite, which, by the weathering away of the shales, become scattered about on the surface of the ground. Small nodules of clay-ironstone are also met with in this way, but are not very common. Shales of the above varieties constitute an important proportion of the entire bulk of the rocks.

The sandstones are usually gray or greenish-gray, more rarely yellowish or pure white; sometimes harsh; generally moderately fine-grained, and often tolerably hard. Sometimes they are intersected by veins of calcspar, or, like the shales, contain irregular nodular calcareous masses. Conglomeritic beds, containing pebbles from two inches diameter, downwards (which are mainly of white quartz), are met with, but rarely, and of trifling thickness.

Both shales and sandstones not unfrequently contain lignite. It occurs in little irregular strings, or in strangulated layers from an inch, or less, up to three or four inches thick, and seldom as much as a foot long. Where these are found they generally occur more plentifully in some beds than others, lignitiferous strata being interbanded with others which contain no carbonaceous matter. Woody structure is frequently seen in such layers, which are often merely the ends of stems that have been crushed flat. Sometimes the stems are only partly converted into lignite, the remainder being silicified, although still black from residual carbonaceous matter. In some cases the lignite contains pyrites. Much larger stems than the above are occasionally met with, one or two that I saw being 18 inches in diameter, and visible for a length of six or seven feet, but they are far from common of such dimensions.

True, seams of coal have also been found—at Tsétamá, in the southern part of Rámri, where several outcrops occur, varying from one to six feet thick;

[1] For this determination I am indebted to Mr. W. Blanford.

[2] Journ. As. Soc., Bengal, XII, 1043.

and near Pallang Roa in Cheduba. Beds of more or less carbonaceous sandstone have been met with in one or two other places. As I shall subsequently have occasion to describe these coal-seams in detail, with reference to their economic value (p. 207), it is unnecessary here to do more than mention their occurrence.

Besides the above strata, some bands of limestone of considerable thickness are to be found, which will be subsequently more fully described (p. 221). One of the most important of these is near Yánthek, where the rock bears some resemblance in aspect to a coarse yellowish-white chalk, but does not mark like it, being as hard as ordinary limestone. It is rather brittle, breaking with a tolerably smooth fracture. The bedding is generally obscure, and masses up to 20 feet thick occur in which none is apparent. A limestone of very similar character also occurs near Tsinbok. In the Pagoda Hill, at the town of Rámri, and again a mile or two further east, a thin band of such rock occurs interbedded with sandstone, and shale of the usual type. South-east of Tsétamá limestone of a different character occurs. It is of a pale gray or grayish-white color, rather hard, not brittle, and instead of the chalky look of the above, has a minutely crystalline structure. It is very massively bedded, and there are, apparently, at least two bands, each not less than 25 yards thick, with sandstone between. At Tengbain similar minutely crystalline limestone is associated with rock of a much coarser grain, which in hand specimens is not unlike some varieties of limestone from the old metamorphic series. Such crystalline limestone, again, at Allé Chaung and Tsáné, is associated with grayish chert, which is very cellular and rusty on the weathered portion, and is intersected by very numerous strings of white quartz: some surfaces of the rock are sprinkled with little limpid rock crystals. Cherty and calcareous seams are irregularly interbanded with each other, the beds with which these rocks are associated being ordinary sandstones. Similar chert, with or without accompanying limestone, is met with not unfrequently elsewhere, but the bands do not appear to exceed a few yards in thickness.[1]

With the exception of the limestone associated with chert at Allé Chaung, which is dolomitic (and contains minute crystals of magnetite disseminated through it), all the limestones I have examined are purely calcareous.

The rocks, generally, throughout the islands, have been greatly tossed about, the strike being far from constant, and the dip extremely irregular. Not unfrequently it is vertical. But owing to the softness of the shales, and their clunchy character, and the facility with which much of the sandstone gets broken up superficially, the lie of the rocks is often very obscurely seen.

It would be certainly rash, on the strength of such a cursory examination as mine, to assert that the rocks throughout the islands belong exclusively to one series, but as far as my observations go, they do not suggest any grounds sufficiently strong for attempting a separation.

The only fossils I observed were some obscure markings in the sandstone at Likmau, and there is so much lithological resemblance between some of the tertiary groups of Burma that little can be gleaned as to the age of the Rámri rocks from their mineral characters. It may be remarked, however, that

[1] Mr. W. Theobald mentions similar chert as occurring in Negrais and nummulitic strata of the Pegu Division: Mem. G. S. I., X, 300.

petroleum-bearing rocks occur throughout the islands, and that the oil-bearing rocks of Pegu, which are within 70 miles of Rámri in a straight line, are believed by Mr. Theobald to be nummulitic, all the known oil localities being situated either on nummulitic or still younger strata.

Again, the coal hitherto found in Eastern India (Assam and Burma) is all either of cretaceous or of nummulitic age, the former being markedly different in external characters from the latter.[1] That from the Rámri Islands bears no resemblance to cretaceous coal, and is quite of the nummulitic type.[2]

Mud Volcanoes. Distribution.

The number of mud volcanoes distributed over the islands is considerable, there being in Rámri itself a dozen or more; more than half that number in Cheduba[3]; three, at least, on Amherst, and two on Flat Island. I have heard of others on the neighbouring part of the mainland, but have no definite information about them. On the opposite side of the Arrakán Range, near Menbo, on the Irrawádi, numerous mud volcanoes exist, which have been described by Dr. T. Oldham,[4] and two are mentioned by Mr. W. Theobald as occurring on the coast not far from Cape Negrais.[5] I myself observed a very small one in the Baránga Islands, and there are records of two sub-marine eruptions. It was reported, on native information, that two volcanoes opened in the Chittagong District during the earthquake of 1762.[6] It would appear, therefore, that salses are rather widely distributed over both flanks of the Arrakán Range. But those in the Rámri group hold the first place in magnitude and in the violence of their paroxysmal eruptions. It will be observed that they illustrate, on a small scale, that distribution into linearly arranged and isolated vents which has been so commonly remarked amongst the great volcanoes of the earth. At Kyauk Phyu six occur in a line within a distance of perhaps a mile and a half along the summit of a low broad ridge. Two volcanoes in close proximity, or with their circumferences even touching each other, occur in several cases elsewhere.

General appearance.

In respect to their form the volcanoes may be divided into *mounds* and *cones*, there being, however, no sharp line between the two varieties. The former are approximately circular, generally varying in diameter from 50 to 100 yards with a height of perhaps 15 to 30 feet; there are, however, two exceptionally large ones in Cheduba, south-east of the Pagoda Hill, respectively about 200 and 250 yards across. The mounds *look* like an accumulation of angular fragments of rock—shale, sandstone, &c., but this appearance is deceptive. During ordinary times mud is ejected in small quantities, and during the greater eruptions, stones and mud are shot out together, the whole forming a sort of unconsolidated conglomerate. The wash of rain, however, scours

[1] Memoirs, Vol. VII, p. 175.

[2] The limestone at Yánthek and Tsinbok (p. 221) apparently closely resembles that described by Mr. Theobald at p. 313 of his report, and which he considers to be cretaceous. That some of the Rámri rocks should be referred to this age is by no means improbable.

[3] *Vide* Captain Halsted's Map, Journ. As. Soc., Bengal, Vol. X, p. 446.

[4] Mission to the Court of Ava; by Captain Yule, 1855; Appendix. p. 339

[5] Mem., G. S. I., Vol. X, p. 119.

[6] Journ. As. Soc., Bengal, XII, 1050, and Phil. Trans., LIII, 251.

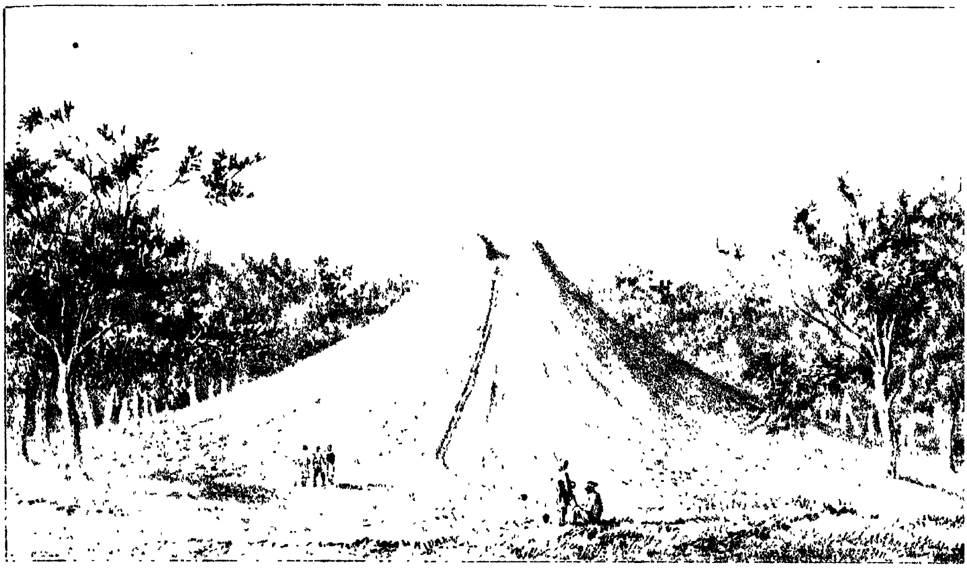
the mud away from the surface, leaving a superficial layer of fragments behind, which thus have the appearance of constituting the whole mass. On digging down a foot, or less, the true composition becomes apparent. There are often cracks, also, which show the mud below, sometimes in a dried, in other cases in a still pasty condition. In the centre of one of the Kyauk Phyu mounds there was a circular space, about 10 yards diameter, where the surface crust, composed of fragments cemented by dried mud, was not more than 9 inches thick, and was intersected by numerous shrinkage cracks through which a ten-foot stick could easily be thrust into the soft mud beneath. The highest part of the mounds is generally at or near the centre, but not always. One of the large mounds south-east of Pagoda Hill has its summit about halfway between the centre and circumference. Scattered over the mounds, more commonly towards the central part, but sometimes at or near the edge, there are generally a few mud cones from a few inches to as many feet in height, with craters at the top containing more or less liquid mud. To these I shall allude again.

The mounds, which are quite bare of vegetation themselves, are surrounded by a ring, varying in breadth, but averaging perhaps 50 to 100 yards, of casuarinas, not very thickly grouped, and unaccompanied by any other trees. Beneath them is thinly scattered grass. Immediately outside this ring the ordinary jungle commences. Casuarinas are only found in the islands along the sea coast and around the volcanoes. They prefer a saline soil, which they obtain in both positions. The mud ejected from the volcanoes is invariably saline, and while favouring the growth of casuarinas, prevents that of ordinary jungle. At the two large salses south-east of Pagoda Hill (and in this case only, as far as my experience goes) the casuarina ring is replaced by one of phœnix palms.

The most perfect examples I have seen of the conical form of volcano are the two salses at Kyauk Phyu nearest the sea. One of these is about 40 feet high from the inner side of the casuarina ring,[1] with a slope increasing in steepness towards the top of the cone, where there is a crater 12 feet in diameter, filled, (at the time of my visit), to within 4 feet of the top, with thickish mud into which a stick 10 feet long could easily be thrust. The other cone is similar, but smaller.

Mounds are commoner than well developed cones. The former would appear to be in an earlier stage of development. The difference in form is partly caused, also, by the mud ejections in the former case shifting their positions at different times to different portions of the mound. Thus at one of the salses south-east of Pagoda Hill, the largest mud craters at present, one of which is 10 feet high, are situated close to the edge of the mound. When such a change of position takes place, the deserted craters, which have not had time to attain any very large dimensions, are washed down by rain into the general mass of the

[1] Owing to the weathered, broken up, condition of the shale and sandstone in the low broad ridge on which the volcanoes are situated, it is rather difficult to distinguish the débris of the former from that ejected from the volcanoes, or to determine how far the ridge has been produced by the latter. The summit of the last mentioned cone is 200 or 300 feet above the sea. Captain Halsted says that the volcanoes in Cheduba vary from 100 to 1,000 feet above the sea level. These elevations, however, include those of the hilly ground on which many of the volcanoes are situated.



J Schaumburg lith

MUD VOLCANOES, WITH SURROUNDING CASUARINA RINGS

RÁMRI ISLAND

mound, so that the latter presents, as before described, the aspect of a heap of stony debris on which only the more recently formed and active mud cones remain. On the whole, however, the ejections are generally more frequent, or more abundant, towards the centre of the mound, which is consequently highest. Occasionally, however, the summit is found elsewhere.

In the case of the second form, the ejections (of sufficiently viscid mud) have remained constant to a single vent, around which the entire mass of matter has by degrees been built up into one cone of regular outline. In the character of the ejected stones, the surrounding casuarina ring, &c., the cones are quite similar to the mounds.

Ordinary conditions of eruption.

On rare occasions the mud volcanoes are subject to paroxysmal eruptions of great violence. In ordinary times, however, they remain in a state of comparative quiescence. Sometimes action is suspended altogether, but generally a few mud cones, from a few inches to as many feet high, are scattered over the mounds, in the majority of cases at or near the centre. The craters at the top contain mud in various degrees of fluidity. Sometimes it is thin and watery; in other cases thick and viscid. The thin mud forms cones of very regular outline, but low inclination; sometimes not more than 15 degrees: the cones produced from viscid mud, on the contrary, rise at steep angles, and are sometimes nearly vertical at the top. In such cases they are formed, in part at least, by small quantities of mud *spirted* out, which drop back on the rim and gradually build it up like a wall. Bubbles of inflammable gas rise through the mud in the craters, when they are active, in greater or less number. When the mud is very thick the gas issues with a peculiar 'clucking' sort of noise, and when sufficiently forcible, produces the spirting just alluded to.

Besides such spirtings, flows of mud issue at times from the craters, generally finding an exit by breaking down the weakest part of the rim. A stream of some magnitude had flowed from the most northern of the Kyauk Phyu conical volcanoes not long before I visited it. Issuing from a gap in the crater wall, with a breadth of 18 inches or 2 feet, it flowed down the side of the cone, with a very constant width. At the bottom it got into a small channel, and continued its course for a distance of 100 yards from its source. The stream well exhibited that canal-like form which sufficiently viscid mud assumes under such circumstances. Owing to the sides moving more slowly than the centre, and hence having more time to dry, the mud there first becomes too consolidated to flow further, and forms banks between which the central portion still flows on. An analogous phenomenon is frequent in lava streams. "A stream of lava," says Mr. Scrope," while flowing down any slope, will, owing to its imperfect fluidity, usually be thickest towards its centre, and consequently possess a convex cross section on its upper surface, the sides rising as steep banks from the uncovered ground adjoining. But when the supply of fresh lava from the vent diminishes or entirely ceases (the still liquid interior at the central part of the current continuing for some time to flow on, urged by its own weight above, down any slope that offers itself), the upper crust, being unsupported, will have a tendency to subside in proportion. Hence we often find narrow lava-streams confined

within banks, which they seem to have raised themselves, and having a *concave* surface in their cross section; the sides, which necessarily cooled sooner than the central part, preserving their thickness, and taking the form of high banks or ridges, between which the internal lava-stream flowed on for some time, as in a canal, the level of its surface gradually lowering as the supply from above ceased."[1]

The sources of the mud are undoubtedly the gray shales which form such an important part of the rocks throughout the islands. Although these are generally brittle and clunchy in a dry state, when thoroughly soaked with water, as they are seen, for instance, along the shore at low tide, they break with a somewhat plastic mode of fracture, and are easily kneaded into mud identical in appearance with that ejected from the volcanoes.

I have not myself observed the mud to possess any sensible degree of warmth, but I was not fortunate enough to witness any actual eruption beyond a mere dribble. That the mud is warm, however, at times, we have the evidence of Mr. Howe, who found "a hot slimy fluid" some time after a fiery eruption from one of the Kyauk Phyu volcanoes. Captain Halsted found mud brought up from a depth of 17 feet at one of the Rámri volcanoes to show "a temperature of 92° 20′, above that of the atmosphere" (*sic;* misprint for 92°, 20° above that of the atmosphere?). Dr. Spry also remarked that the crater of one of the Kyauk Phyu volcanoes, 12 feet in diameter, "was filled with warm liquid mud."

The ejected mud always contains more or less saline matter, which is principally common salt. Occasionally, however, this salt is mixed with a large proportion of sodium sulphate, and contains calcium sulphate besides. It has been suggested that the salt is derived direct from sea water,[2] and Captain Williams even mentions having received a fish which was *said* by the natives to have been thrown up by one of the Kyauk Phyu volcanoes.[3] This idea, however, is scarcely supported by the want of uniformity in the composition of the salt, and it is, I think, probable that the latter is derived in considerable part from the rocks themselves that yield the supply of mud. The intimate connection between the petroleum and mud volcanoes of Rámri will be subsequently alluded to, and it is well known how frequently mineral oil and salt are associated. In India they are found together in the oil-producing tracts of Burma, Assám, and the Punjáb.[4] That the Rámri rocks do contain saline matter I found by examining the shales or clays from the oil-wells of Tsi Cháng, Létaung, and Minbain, which when lixiviated with water all yielded soluble chlorides and sulphates in varying proportions. Further, it appears from Dr. Oldham's account that the mud from the craters at Menbo on the Irrawádi, some 70 miles from the sea in a straight line, is saline also, and is largely used for the preparation of salt by lixiviation.

Water in considerable quantity is, of course, a necessity for the production of the often slushy mud ejected by the Rámri salses, and that this in some

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1 Volcanoes, p. 76.

2 Trans. Bombay Geol. Soc., X, 146.

3 Journ. As. Soc., Bengal, XII, 334.

4 Rec. G. S. I., VI, 70: Mem. G. S. I., XII, 356; XI, 129.

cases infiltrates from the sea is by no means unlikely, but in others, where the volcanoes are two or three miles from the coast or any creek, it would appear not improbable that the water is derived from surface percolation. Saltness is a very common characteristic of mud volcanoes, as is indeed indicated by the term *salse*[1] often used for them.

Paroxysmal eruptions.

Although the emissions from the volcanoes in their ordinary condition are of the above described insignificant character, at uncertain (and sometimes long) intervals, eruptions of a much more violent character take place. At such times mud and stones are shot out with great force and noise, accompanied by large quantities of inflammable gas, which in many cases catches fire and gives rise to a volume of flame that lights up the country for miles around. Of course such eruptions vary in intensity, some being much more violent than others. I was not fortunate enough to see anything of the kind, but there are several records of their occurrence.

From one of the Kyauk Phyu volcanoes, Dr. McClelland states, that "vapour and flame were seen by the inhabitants of Kyauk Phyu to issue to the height of several hundred feet above the summit during the principal shock of the earthquake of the 26th August 1833[2]." This was a violent earthquake felt, amongst other places, at Calcutta, Agra, Nepál, and Lássa.

On the 23rd of March 1839 a very severe earthquake was felt throughout the whole of Burma, during which "fires, mingled with smoke and ashes, rose to a fearful height" from one of the same group of vents.[3]

Mr. Howe, Marine Assistant at Kyauk Phyu, thus describes an eruption which occurred on the 6th of February 1843:—"We had, last night, a most magnificent volcanic eruption. The mountain, which is of moderate height, and shaped somewhat like a pyramid, is about three or four miles from the station, which was rendered as light as noon-day, though midnight at the time. The eruption commenced at about 11 P. M., unaccompanied by any rumbling, but throwing up masses and particles of lava (*sic; vide* p. 202) to an immense height, and presenting a most magnificent spectacle, visible all round the country. The weather had been for some evenings previous close and threatening, though the glass kept up, varying from 30° 12′ to 29° 98′ for the last five or six days.

"The fire gradually went out, and all was still again by about half an hour after midnight.

"This eruption takes place, from what I hear, generally once in two years, sometimes annually."[4] Subsequently—how long does not appear—Mr. Howe wrote,—"The volcano is still in a bubbling boiling state, the orifice not larger than a tea cup, and there is a hot slimy fluid to be dipped up at the surface, but no vapour or noise is emitted, and it is otherwise quiet."[5] As no vapour was emitted

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[1] From *salsus*, salted.

[2] Report of a Committee for investigating the coal and mineral resources of India (1838), p. 41.

[3] Silliman's Journal, XXXVIII, 386—British Association Earthquake Catalogue.

[4] Journ. As. Soc., Bengal, XII, 256.

[5] *Ibid.*, 521.

the "boiling" spoken of was doubtless the escape of gas. The orifice must of course have been of considerable dimensions during the eruption on the 6th of February. Subsequently to that date, when the violent stage of the eruption was over, a mud cone, similar to those described above, was probably quietly built up over the spot, with a crater of the size mentioned.

Between the 26th and 29th of July 1843, an eruption took place "at a distance of about thirty bamboos" south of False Island, which a few months afterwards was described as follows by natives of Cheduba and Flat Island to Captain Russell, commanding the H. C. steamer *Ganges*: "About our morning meal, or 7 or 8 o'clock on the morning of the first day, we heard a great noise, and saw fire rising out of the sea, which continued for four days; on the second day we saw a small island newly formed in the sea, between 'Flat Rock' and 'Round Rock,'[1] about the size of the sandbank called False Island.

"We saw the newly formed island for a month, but could not approach it on account of the boisterous sea on the coast. We felt an earthquake before we saw the fire in the sea; in the month of October we came out in our boats to look for the island, but saw nothing. The rocks, as they now lay, are of the same number and position as before the appearance of the new island."[2] Captain Russell found two and a half to three fathoms of water over the spot where the island had been, with a rocky bottom. The ejecta during such eruptions being exclusively mud and stones, none but the largest among the latter would have any power of resisting the waves during the south-west monsoon.

"On the night of the 2nd of January 1845," Ensign G. Hankin, 66th Native Infantry, wrote, the day after the occurrence:—"Between the hours of 6 and 7, a very interesting and singular phenomenon was observed off the coast of Kyauk Phyu. The sky on the horizon was observed to brighten up as when illuminated by the rays of the setting sun, except that the light more resembled the flickering of a fire than the gradual descent of that luminary. It continued in this way for half an hour or so, when all of a sudden immense volumes of flame were seen to issue as it were from the depths of the ocean, presenting the most sublime yet awful spectacle to the beholders. The general idea entertained was, that a ship had caught fire; but this was soon dispelled by a low continuous rumbling, which seemed to sound from the bowels of the earth, and was re-echoed by the surrounding hills. Previous to this, however, Captain Howe, the Marine Superintendent, had with the greatest promptitude set off in H. C. schooner "*Petrel*," intending to render assistance to the supposed unfortunates of the burning ship; he returned without seeing anything, and it is thought that the whole was the result of some hidden volcanic agency; one of the neighbouring hills possessing that extraordinary property, and from which flames have been seen to issue before. The weather at the time was still and serene, hardly a breath disturbed the air: it was in fact, as some one observed, a very earthquaky day."[3] According to Captain Williams' account "the reflection of the flame was made on a dark bank of clouds, west of the station, on the track of ships from hence

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[1] Not to be confounded with Flat and Round Islands.

[2] Journ. As. Soc., Bengal, XII, 832, 1116.

[3] Journ. As. Soc., Bengal, XIV, 1845, Proceedings for February.

to Calcutta: it flickered several times as if the fire had been got under, and after lasting 15 or 20 minutes (say) suddenly went out. Various were the conjectures: I thought it was the reflection of the sun from below the horizon, but the sudden light of flame was too brilliant and unsteady to be the sun's light; electricity in the cloud was stated to be the cause, but this is not the season for such a cause: 'a ship on fire,' said many; but this morning the prevailing opinion is, that a volcanic eruption has taken place 20 miles out to sea, similar to what I reported as having taken place near Cheduba. The argument against its having been a ship on fire is, that the flame showing so brilliant and so great a light could not be so suddenly extinguished as this was, the dark bank of clouds may have been formed of the smoke of the volcano."

The light was also seen by Captain Siddons and others from Akyab, and from the H. C. schooner "*Spy*," then off the Assirghar shoal (about 30 miles north-west of Akyab), the Commander of which ship saw "five different times large masses of fires thrown up," which he supposed to be a volcanic eruption. It is scarcely open to doubt, however, that what was seen from the "*Spy*," at least, was the reflection of the fire from the bank of the clouds alluded to by Captain Williams, and not the flames themselves. The bearings taken from the above different places showed the position of the fire to have been about 7 miles S. $\frac{3}{4}$ E. from the south end of the Western Baránga, the distance from Kyauk Phyu being 31 nautical miles, from Akyab 28, and from the Assirghar shoal 57. As Kyauk Phyu and Akyab are both on alluvium, it is not probable that the observers in any case were more than 20 feet or so above the sea. Taking, therefore, the curvature of the earth (with refraction) into account, the flames to have been themselves visible at the above distances must, with reference to each position respectively, have exceeded 500, 400, and 2,000 feet in height!.[1]

Soundings were made within a few days of the occurrence, but no difference from the soundings laid down on the chart was discovered.

An eruption, on a comparatively small scale, which took place from one of the Kyauk Phyu volcanoes on the 25th of October 1846, was thus described by Major Williams:—"About a quarter to 9 o'clock last night, we had an eruption of one of our volcanoes near the village of Chein Kroong,[2] about three or four miles from this station, on the island of Rámri; it burst out suddenly with a slight noise, emitting a brilliant flame, which instantly went out, and again burst forth; this happened for fifteen or twenty times, when the flame burnt steadily, gradually diminishing, and disappeared altogether about daybreak, or a little before it, this morning: it rained heavily all the time.

"The whole sky was illuminated brilliantly, and again suddenly everything was immersed in darkness during the flashes, and then sudden disappearance, which I can only compare to the effect, on a small scale, of a handful of oil, or any

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[1] Humboldt mentions an eruption from a mud volcano near Baku, when the flames flashed up to an extraordinary height for three hours, and another in the same region during which the flames rose so high that they could be seen at a distance of 24 miles (Kosmos I). It is stated by Eichwald that the eruptions there always terminate with a pouring out of naphtha (Edin. New Phil. Journal, XIV, 132).

[2] Tsi Cháng?

combustible matter being thrown into a fire " ... "I have had a more correct description of the volcano to-day" : (28th) "The size of the crater is about six feet in diameter only, surrounded on all sides, to some extent, with soft mud knee-deep, and the jhow or cassuarino trees growing around unhurt, in a regular manner as if planted there; no other kind of trees near, and of course all other vegetation covered with the mud thrown out. It is still burning, and it is just now a place of resort by these superstitious people who make offerings to the Naga, the cause of earthquakes and volcanoes. It appears that there is no hole where the flame (still burning and about two feet high) issues from, it comes up through the soft mud."[1]

According to some of the head men of Tsi Cháng whom I questioned, the time that has elapsed since the latest eruption from each of the different Kyauk Phyu volcanoes is roughly as follows:—

	Interval since last eruption.
1st (most southerly) volcano	17 or 18 years.
2nd "	10 years.
3rd "	Erupts almost yearly.
4th "	Extinct.
5th "	3 or 4 years.
6th "	?

The eruptions are only sometimes accompanied by flame. Four years ago there was a great eruption of the 3rd volcano: the heat given off by the flames was then so great that the villagers could not approach near, but looked on from behind the shelter of the neighbouring jungle.

There is a story well known over Cheduba and which was told to me, amongst others, by the Burman Extra Assistant Commissioner and by the head man of Kanthào Roa: although largely mixed up with fable, there would appear to be a substratum of fact, and it serves, at least, to illustrate the ideas held by the islanders themselves regarding their volcanoes. About three years ago, as it is said, a party of nine people from the village of Kaindi Roa, went to the Pagoda Hill to worship, one of the party being a man named Ngalaitké, which means a turtle in Arrakánese. On their return, and while passing over one of the large volcanic mounds near the Pagoda Hill, one of the men called out mockingly to the Nagá—a spirit in the form of a serpent that presides over each volcano—"O! Nagá Ji, here is a fine turtle I have brought; let me have some fire to cook him!" The offended Nagá granted his wish. Flames issued from the volcano. Four of the party were consumed and the remainder escaped more or less injured. The Extra Assistant Commissioner, while telling me the tale at Kanthào Roa, sent for a woman who was said to have been amongst the number, and who was marked with large scars like those produced by severe burns, which she said she had received on the occasion referred to. She had not, however, herself heard the insult offered to the Nagá. This part of the story will perhaps strike the sceptical as being open to some doubt, but that flames did issue suddenly and injure the people is, I am inclined to believe, a fact. It may be observed that in some of the preceding records, also, the eruptions are said to have had a sudden commencement.

[1] Journ. As. Soc., Bengal, Proceedings for November 1846.

There is a notion prevalent amongst the islanders that eruptions, from the volcanoes generally, take place more frequently during the rains than at other times of the year, an idea which can scarcely be considered as borne out by the few dates of eruption on record. Those mentioned above are respectively—

January 2nd.
February 6th.
March 23rd.
July 26th.
August 26th.
October 25th.

A greater tendency of eruption at certain times of the year has, however, been suspected to exist in some other parts of the world. It is stated by Dr. Horsfield that the eruptions from the mud volcanoes of Java are more violent during the rainy season than at other times,[1] and M. Dubois de Montpéreux mentions that out of six eruptions from the mud volcanoes near the entrance to the sea of Azov, five occurred between February and the 10th of May, the only known autumnal eruption having been on the 5th September.[2]

Ejected stones.

The vast majority of the ejected pieces of rock are from half an inch, or less, to 4 or 5 inches diameter. Stones of half a cubic foot are not very common, and those of a foot rare. On the large mounds south-east of Pagoda Hill, however, there are a few blocks containing 3 or 4 cubic feet, or more, of rock. The height to which some of the stones have been thrown may be gathered from the distance from the mound to which they have been scattered over the surrounding phœnix ring.

The ejected stones are, without exception, fragments of the various kinds of rock found in the neighbourhood of the volcanoes, the great mass being shale and sandstone. These are often penetrated by veins of calcspar, and occasionally contain strings of lignite. Pieces of more or less impure limestone, also, are not uncommon. Bits of pyrites are occasionally found, but are far from plentiful.[3]

Very rarely indeed do the stones show any definite signs of alteration by heat. The only case I observed was that of some fragments of red shale, different in color from anything observed *in situ*. On exposing fragments of gray shale, however, from some of the oil wells, to a red heat over a Bunsen's burner, they became first dark colored and then red. Mr. Piddington mentions having received, amongst other specimens sent by Mr. Howe from the Kyauk Phyu volcano after the eruption of February 1843, a specimen which was "gray shale at one end and brick-red clay slate at the other, with the dark half-calcined-shale in the middle."[4] Captain Halsted alludes to "a white stone, like chalk, found on all the large volcanoes, which was considered as the common greenish sandstone discolored by heat." The bleached-looking appearance of this rock, however, is deceptive.

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[1] Daubeny on volcanoes, p. 409.

[2] Geological Observer, p. 475. Also Verneuil: Mémoires de la Société Géologique de France, III, p. 4.

[3] Spoken of as "copper ore" by Captain Halsted, who also mentions "silver ore." The latter was conjectured by Mr. Piddington to have been marcasite, but no specimens were forthcoming for examination. (Journ. As. Soc., Bengal, X, 443, 449).

[4] Journ. As. Soc., Bengal, XII, 336.

It is merely a fine-grained, slightly calcareous, white sandstone, which I have observed more than once *in situ* near the volcanoes.

No products of fusion ejected.

Mr. Howe alludes to "masses and particles of lava" thrown up from one of the Kyauk Phyu volcanoes during the above mentioned eruption. Lieutenant Foley, also, says that at one of the craters in the same neighbourhood "scoriaceous matter, trap minerals, and basalt show evidence of more active volcanic agency in times past.[1]" This statement is, however, completely erroneous. I have visited every one of the Kyauk Phyu volcanoes, and (knowing beforehand what had been written) failed to find a single particle of basalt, lava, scoriæ, or any other rock showing even a trace of fusion. The 'hard and sonorous rock resembling clinkstone, of a sea-green color and intersected with veins of calcspar,' found by Lieutenant Foley at the foot of one of the Rámri volcanoes, and conjectured by him to have been ejected in a state of fusion, was most probably a hard, fine-grained, greenish sandstone with calcspar veins through it. A rock of this kind may be seen, amongst other localities, on Flat Island. In another place, indeed, Lieutenant Foley says that "a few blocks of sandstone, and a conglomerate, consisting of a paste of sandstone, with enclosed nodules of a calcareous earth, lay upon the beach; some of these rocks had a scoriaceous appearance, were encrusted with crystals of iron pyrites, and bore evident marks of igneous origin."[2]

Gaseous emissions.

The inflammable gas which is evolved from the volcanoes, in bubbles during ordinary times, and in enormous quantities during the most violent eruptions, is evidently, in the main, marsh-gas, mixed probably with a varying proportion of other gases. During great eruptions it is not improbably mixed with the vapor of the more highly volatile of the petroleum hydrocarbons, as well as, perhaps, with the heavier hydrocarbons blown out in a state of spray. That a certain amount of heat is connected with such eruptions is evidenced by the hot or warm condition of the mud;[3] but the unaltered state of the ejecta, especially such substances as lignite and pyrites which would undergo decomposition if strongly heated, show that the temperature is not very high. It is, I think, improbable that the gas issues during eruptions at a sufficiently high temperature to ignite spontaneously. The cause of its ignition may, perhaps, be inferred from the phenomenon frequently observed during eruptions of fragmentary ejecta from volcanoes in the usual sense of the term, like Vesuvius. During such times "forked lightnings of great vividness and beauty" are continually darted from the ascending column of stones, scoriæ, dust and more or less condensed vapor, the electricity being developed by the friction of the ejecta amongst themselves.[4] The principle of the hydro-electric machine is very similar, in which large quantities of electricity of high intensity are produced by the issue of partially condensed steam through small orifices of such form as to create considerable friction. From a large machine of this kind a battery has been charged in half a minute which gave sparks 22 inches long.[5] In the case of the mud volcanoes, when

[1] Journ. As. Soc., Bengal, II, 597.
[2] Journ. As. Soc., Bengal, IV, 28.
[3] p. 196.
[4] Scrope's volcanoes, pp. 22, 57.
[5] Watts' Dictionary of Chemistry, II, 408.

quantities of stones, and of mud, doubtless reduced to spray by the violence of the action, are being shot into the air, the friction of the ejecta amongst themselves, must necessarily produce large quantities of electricity, and it is, I believe, to the sparks, or lightning on a small scale, thus produced, that the ignition of the gas is due. The flames at the surface are sufficient to account for the calcination of the fragments of shale mentioned above.

It will be observed that the fire of the mud volcanoes differs from that so often popularly spoken of in connection with lava-emitting volcanoes, in that the former is due to real flames, the latter being the reflection of the light from glowing lava by masses of condensed vapor, or of dust and scoriæ, or, in other cases, the light from jets of incandescent lava-drops.

Extinct mud volcanoes.

In the mound south of Kyauk-galé we have an instance of a mud volcano in an almost extinct, or, at any rate, long dormant condition. Instead of the usual heap of bare stony-looking debris, the mound is clayey at the surface and covered thinly with grass, with a few scattered casuarinas around. When I saw it there was one small mud cone at the centre from which bubbles of gas were being given off, but the amount of mud recently ejected,—*i. e.*, covering, instead of covered by, grass,—did not exceed a few cubic feet. The mound, about 100 yards in diameter and perhaps 15 feet high, is situated on a raised beach, whose present elevation of about 20 feet above the sea only dates back to the middle of the 16th or 17th century.[1] Previous to that time there may of course have been submarine eruptions, but if so, the loose ejecta must have been carried away by the sea. The present mound can never have been exposed to the surf, and as it is now very nearly extinct, the maximum length of its period of subaërial activity can be inferred.

The third of the Kyauk Phyu volcanoes, counting from the sea, is in a still more advanced stage. It is a cone of low gradient, with a depression a few yards in diameter at the summit, containing a pool of water bordered by rushes—a miniature crater lake. The cone is thinly overgrown with grass, and casuarinas are dotted over it accompanied by other trees. After eruptions have ceased, the salt is gradually washed out of the debris by rain; slowly probably on account of the impervious character of the mud. The cone thus by degrees becomes less fit for the growth of casuarinas, and more suited to that of ordinary jungle, which ultimately doubtless usurps the place of the former trees completely.

Origin of the mud volcanoes.

I have already alluded to the position of the Arrakán salses at or near the end of the great Sunda group of volcanic vents. The next to them are Narkondám and Barren Island, both of which are volcanoes in the ordinary sense of the term.

There is of course a wide gulf between the two classes of volcanic phenomena. Indeed some authorities, like Dr. Daubeny and Mr. Scrope, do not regard salses as truly volcanic at all, grouping them as pseudo-volcanic phenomena.

For the production of any volcanic cone three main conditions are necessary: 1*st*, the reduction of rock at a greater or less depth beneath the surface to a mobile condition; 2*nd*, a practicable vent by which such rock can be forced to

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[1] p. 190.

the surface; and *3rd,* the presence of a power competent to force it up to the mouth of the vent and leave it there to reconsolidate. In the case of 'true' volcanoes the mobility is *in the main* gained by the reduction of rock to a state of fusion, the heat involved in the process being due, as has been shown by Mr. R. Mallet, to local crushing of the earth's crust, caused by the secular refrigeration of the globe, the interior cooling, and consequently contracting, faster than the exterior, which is thus subjected to tangential thrusts. The force by which the lava is ejected is the pressure of steam raised to a high temperature by heat derived from the same source as that which fuses the rock.[1]

In the case of salses the mobility is produced by reduction of rock to a state of mud, either by partly chemical, or by purely mechanical means.[2] The ejecting force is sometimes the pressure of steam; in other cases, including the Arrakán salses, it is, mainly at least, that of gaseous hydrocarbons.

Amongst the most prominent examples of steam mud volcanoes are those in New Zealand, described by Dr. Hochstetter, where are craters filled with boiling mud from which steam escapes explosively at intervals, accompanied by sulphuric acid and other gases, to whose action on the lavas underground Dr. Hochstetter attributes the origin of the mud.[3] Of a similar character are the boiling mud volcanoes of Iceland, which have been described by Professor Paijjull, Captain C. S. Forbes, and others. Such also are the mud volcanoes of the Colorado desert. From some of these "the steam rushes in a continuous stream, with a roaring or whizzing sound, as the orifices vary in diameter or the jets differ in velocity. In others the action is intermittent, and each recurring rush of steam is accompanied by a discharge of a shower of hot mud, masses of which are thrown sometimes to the height of a hundred feet."[4]

In all the above cases the mud cones are in the closest relationship with existing, or but recently extinct, phenomena of volcanic fusion; the mud is produced by chemical action of acid gases on volcanic rocks, and the steam is generated by the heat which originally fused these, or by heat which has been produced in the same way. The heat required, however, is of a much lower degree of intensity, and hence such steam mud volcanoes may long outlive the immeasurably grander phenomena of the lava-emitting period. It is of course necessary that the springs should be *boiling,* steam at considerable pressure, but whose force is dissipated at the vent, being the power involved. A spring of water merely, whether hot or cold, bearing a certain proportion of mud to the surface, would be equally capable of carrying it away from the mouth of the vent, so that although a deposit might be formed, it could not be in the form of a crater-bearing cone.

The volcanoes of Rámri belong to a different class. There the mud is not produced by chemical means, but by mere mixture of shale and clay with water. The ejecting force is evidently the pressure of gas, which is in large part, at least,

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[1] Phil. Trans., 1873.

[2] In both fusion and mud volcanoes mobility is conferred on a certain proportion of rock by mere breaking up sufficiently small to admit of ejection along with the fluid materials.

[3] 'New Zealand,' pp. 401, 432.

[4] Silliman's Journal, XXVI, 292.

light carburetted hydrogen, mixed perhaps with the vapor of the most volatile liquid petroleum hydrocarbons.[1] Bubbles of this gas are given off from the mud cones in their ordinary state, as well as from most of the petroleum wells. There are two of the latter at Létaung, about 25 and 40 feet deep, from which the issue of gas is so considerable that it can be heard bubbling up when standing some yards away from the mouth. I roughly guessed the amount at a cubic foot every few seconds, and the villagers say that the well has been in its present state, without diminution of either oil or gas, for many years. Here the gas is being continuously and quietly evolved. The quantities that (having probably gradually accumulated in fissures during long periods) are suddenly liberated during violent eruptions of the volcanoes, may be inferred from the foregoing records.

Recollecting the great tension at which quantities of gas are often stored up in coal mines, and the force with which it escapes from the 'blowers' there, as well as from many bore-holes in the oil regions of America and elsewhere, it is not difficult to conceive that in some cases gas mud volcanoes may be caused, where the other necessary conditions are present, by the pressure of gas due merely to its continued slow generation from carbonaceous matter at the normal temperature of the strata at moderate depths. But given certain coal- or lignite-bearing rocks, producing oil and gas; if they are situated on a line of volcanic heat (although of low intensity, insufficient to fuse, or materially alter, the rocks accompany such carbonaceous matter), the tension of the gas and vapor may, doubtless, be greatly increased by the larger proportion of gas, compared to that of oil, produced at the higher temperature, and by the increased tension due to a higher temperature, where gas is stored up in a fissure of given capacity. In this connection the difference between the petroleum of the Irrawádi valley and of Rámri may be noticed. The mud volcanoes of the former region have been described by Dr. Oldham as very sluggish, and as never exhibiting the fiery paroxysms to which those in Rámri are subject. At the same time the oil is dark colored, is as thick as treacle, or even solid, at 60° F., being indeed often spoken of as 'Rangoon tar,' and contains paraffine to the extent sometimes of more than 10 per cent. The Rámri oils are associated with much gas, and are themselves sometimes as transparent and light colored as brandy. They have a lower specific gravity than the above, and at 60° are perfectly mobile. Without venturing to assert that the above differences are due to a difference in the temperature at which the oils have been produced,[2] it may be noticed that at Baku on the Caspian, where there are mud volcanoes

[1] Whether the temperature of the emitted gases from the Rámri saises is ever sufficiently high to allow of steam playing any important part is a question as yet undetermined. Amongst other mud volcanoes which are intimately connected with petroleum may be mentioned those of Java; those near the eastern shore of the Caspian; at Baku; and near the entrance to the sea of Azov; those near Girgenti in Sicily; and along the northern flanks of the Apennines by Modena and Parma, and those in the Island of Trinidad.

[2] The occurrence of fragments of unaltered lignite amongst the ejecta from the Rámri volcanoes, although one amongst many indications that the subterranean temperature is far below that beneath fusion volcanoes, does not necessarily prove that the temperature may not be considerably above the normal one for the depth, as such fragments may have been torn from the upper part of the vent.

subject to fiery eruptions, similar to those of Rámri, the oil is in part of the same pale transparent kind, and is accompanied by immense quantities of gas. Abich found the temperature of the soil there to be 59° F., of the naphtha 62·5° to 66°, and of the gas-springs 68·5°, and Bischof considered that "the low temperatures above given of the exhalations of Abscheron, where volcanic action in the depths might be conjectured, exclude the notion that heat has any share in their formation.[1]" Eichwald, however, arrived at a different conclusion. "Near to Baku," he wrote, "about one-fourth werst from the perpetual fire, a heat rises out of a fissure of the shell-limestone, which is so strong that the hand can scarcely bear it: hence, from all these circumstances, we can scarcely doubt of the existence of a subterranean heating process in the peninsula of Abscheron."[2] Sir R. Murchison, also, has expressed the opinion that the mud volcanoes of the Caucasus "have a deep seat, and are as directly connected with internal igneous agency as any other geological phenomena of eruption.[3]"

Connection between paroxysmal eruptions and earthquakes.

The evidence is clear as to the intimate connection of the Rámri salses with seismic phenomena at least. Out of the few eruptions of which accounts have been printed, three certainly, and probably four, were synchronous with earthquakes. During the principal shock of the violent earthquake on the 26th August 1833, it is stated by Dr. McClelland that flames issued to a height of several hundred feet from one of the Kyouk Phyu salses. A similar occurrence took place during the earthquake of the 23rd March 1839. The submarine outburst near False Island of the 26th July 1843 was immediately preceded by a like disturbance. Further, during the great earthquake of 2nd April 1762, two volcanoes are said to have opened in the Chittagong District. If these really were volcanoes, and there seems no reason to question it, they were doubtless of the same class as those in Rámri. The connection in some cases may lie in the shock sufficiently loosening the superincumbent rock to allow the pent-up gas to force a passage: in others, it may perhaps be due to a diminution in the size of the fissure, either momentarily during the passage of the wave, or permanently from a partial falling in of the sides. In either case a sufficiently increased tension of gas might be produced to bring on an eruption. It is noticeable that during the earthquake in the last century, when the islands were elevated several feet, no eruptions are recorded, and it is specially mentioned that none took place in Cheduba. In the Chittagong District, during what was probably the same earthquake, the ground was depressed, and two new volcanoes are said to have broken forth.

Mud volcanoes elsewhere in India.

Besides the mud volcanoes in the various localities along the flanks of the Arrakán Range, mentioned at page 193, the only phenomenon of the kind in Eastern India that I am aware of occurs in Upper Assam. It is thus described by Captain Hannay:—"At Namtchuk Pathár, near the mouth of the river, the petroleum exudes from the banks, and a bed of very fine coking coal runs across the bed of the Namtchuk. The hills here are also intersected by ravines, and in

[1] Chemical Geology, I, 252, 257. [2] Edin. New Phil. Journal, XIV, 132.
[3] Russia and the Ural Mountains, p. 576.

one spot an extensive basin or hollow is formed at some height, which contains muddy pools in a constant state of activity, throwing out, with more or less force, white mud mixed with petroleum. This is indeed a strange looking place, and I am told by the Singphos that at times there is an internal noise as of distant thunder, when it bursts forth suddenly, with a loud report, and then for a time subsides.[1]"

On the borders of Western India, in the Beluchistáni District of Lus (north-west of Karáchi), numerous mud volcanoes are scattered over a large area. They have been described by Captain Hart,[2] and subsequently by Captain Robertson[3]. A copy of one of the latter officer's sketches may be found in Lyell's Principles of Geology. Although some of the cones there would appear to be on a larger scale than those in the Rámri group of islands, no mention is made of violent eruptions, either with or without flames,[4] nor of ejected stones. In one case, indeed, Captain Hart specially mentions that the entire cone is of mud, without stones. If eruptions at all resembling those of the Rámri salses had taken place within the memory of the then existing generation, the above observers could scarcely have failed to hear of them. It would seem as if the cones have been raised by emissions of mud, insignificant individually, but continued during lengthy periods, or else that the period of violent eruptions is over, and that the stony ejecta have been covered by the later more tranquil emissions of mud alone.

ON THE MINERAL RESOURCES OF RÁMRI, CHEDUBA, AND THE ADJACENT ISLANDS, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

Coal.

In 1877 the existence of coal in the southern part of Rámri was brought to the notice of Colonel Sladen, Commissioner of Arrakán, by Mr. W. Savage, who had examined the coal-bearing locality, and who forwarded a short memorandum on the subject. In this he described the excavations he had made at Tsetamá, and pointed out the favourable position of the coal with regard to water carriage. The Hon creek, Mr. Savage remarked, is navigable for boats of 6 or 8 tons to within a quarter of a mile of the coal, while the mouth of the same creek is open to vessels of 500 tons. Specimens of the coal, sent to the Geological Museum, proved on assay to be of passable composition. Subsequently I was directed to visit the islands and examine this locality, as well as any others in which indications of coal had been observed.

Previously to my visit, Mr. Duke, the Deputy Commissioner, had issued instructions to the Tehsildárs to send information, accompanied by specimens, of any coal-like substances known to occur in their respective townships. Altogether

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[1] Journ. As. Soc., Bengal, XIV, 819. [2] Trans. Bombay Geograph. Soc., II, 87.

[3] Journal Bombay As. Soc., III, 8 (January 1850).

[4] Captain Robertson mentions that a lighted stick held over an aperture from which bubbles of gas were escaping produced no effect. It would be somewhat rash, however, on the strength of this solitary and somewhat rough experiment, to assume that the gas generally is non-inflammable.

specimens were received from eight different places, all of which I went to. The coal at five of them, however (*viz.*, Pharungjuan Island, about 10 miles north-east of Kyauk Phyu, Then Chaung, Kángautau, Thitpoktaung and Sengu), turned out to consist merely of lenticular nests of lignite, or of stems, partly carbonized and partly silicified, such as have been described in the foregoing paper (p. 191). As sources of fuel they are of course perfectly useless, and do not need any further remark. The coal at Tsetamá, and near Pallang Roa in Cheduba was found to occur in true beds. As I have already briefly sketched the geological character of the Rámri strata, I may here proceed at once to describe the coal itself.

West of Tsetamá.

The locality where the best seams, hitherto found, outcrop is rather less than a mile west-10°-north of Tsetamá village. In the bed of a small nulla, at a spot some 30 feet above the foot of a range of hills, which are a few hundred feet high, and composed of sandstone and shale, the following section (given in descending order), was exposed by digging:—

	Ft.	In.
Gray shale, seen	3	0
Coal, with two or three thin partings of carbonaceous shale	6	0
Brown shale, seen	1	6

Dip south-20°-west, at about 50.°

Fifteen yards lower down the nulla there is another outcrop, of which the section is as follows:—

	Ft.	In.
Shaly sandstone, seen	3	0
Shaly coal	0	8
Carbonaceous shale	0	1
Coal	0	4
Carbonaceous shale	0	3
Coal	1	1
Gray shale, seen	2	0
Coal in seam	2	1
Carbonaceous shale	0	4
Thickness of seam	2	5

Dip west, at 50°.

The coal in both seams is somewhat shaly looking as a whole, although some layers are much better than others. It is strongly laminated; and this, combined with jointing, causes most of it to break up small. The greater portion cannot be extracted in lumps. Some improvement in this respect might, however, be hoped for at a greater depth, with respect to freshly raised coal, but such coal would probably not admit of storage for any length of time without deterioration. The above outcrops remind one much of those of the inferior coal seams in Upper Assam, which there is some reason to believe are of the same age. I have shown in another report[1] that some of the coal there when freshly raised from a moderate depth is hard and firm, but falls to pieces after being exposed for a time. The specimens sent by Mr. Savage underwent a similar deterioration

[1] Mem. G. S. I., XII, 346.

within two or three months, due mainly to the production of minute crystals of copperas from oxidation of the pyrites in the coal.

Several pits were sunk by Mr. Duke's orders on the hill side a little above the nulla. Coal was obtained in some of these; it, however, probably belongs to the same seams. The strike is very irregular.

A little below the 2′ 5″ seam there is one of very fair coal; but it is only about a foot thick.

North-east of Tsetamá.

On a low hill north-east of Tsetamá, or about a mile and a half east-north-east from the last locality, the following section was exposed:—

	Ft.	In.
Brownish shale, seen	2	0
Carbonaceous shale	0	7
Brownish gray shale	0	1
Carbonaceous shale with some *coal*	0	7
Grayish shale, seen	1	6

Dip south-30°-west, at 80°.

Near to this there is a spot where fragments of coal are strewn about, and from which, the villagers with me said, Major Williams had dug some coal about 30 years ago. His excavation is, however, now filled up, and after several attempts I failed to unearth the outcrop.

Pallang Roa.

In a small stream descending the hill north-east of Pallang Roa, in the southern part of Cheduba, three spots were pointed out to me about 30 yards apart. In one of these was a bed of coal 2′ 6″ thick, with brownish gray shale above and below it, dipping east-20°-south at 40°. It is similar in appearance to the brittle coal at Tsetamá. In the second spot there was merely a few inches of carbonaceous shale, and in the third two or three feet of a more recent sandstone containing angular fragments of coal similar to that in the 2′ 6″ seam.

South of Pagoda Hill.

Discoveries of coal have also been reported from more than one locality elsewhere. Thus Captain Halsted in 1841 described a seam which occurs less than a mile from the beach to the south of Pagoda Hill. It dipped at a high angle and was three and a half feet thick, but appears to have been carbonaceous sandstone rather than coal. Captain Halsted "could not make it ignite, it only smouldered."[1]

Near Kyauk Phyu.

Coal was also reported from near Kyauk Phyu in 1833, and some excavations made to expose the outcrops. One seam is described as being nearly vertical, from six inches to a foot in thickness, and as containing much pyrites. Coal was found in one or two other places also in small quantity, but the descriptions given lead one to suspect that it was nothing more than carbonized stems.[2]

A spot was pointed out to me at the north-west corner of Tongreh Island (about 10 miles north-east of Kyauk Phyu), from which some black stuff had been brought. It had been dug from an irregular bed, three to six feet thick, of

[1] Journ. As. Soc., Bengal, X, 444.

[2] Journ. As. Soc., Bengal, II, 595; X, 144.

carbonaceous sandstone, containing perhaps 15 per cent. of combustible matter. As fuel, it was of course quite useless.

Prospect of working Tsetamá coal.

It will be seen, then, that the indications at Tsetamá are much more promising than those anywhere else, and it remains for me to give my opinion as to the prospect of successfully working the coal there.

I have already pointed out that, like that of Upper Assám, it may be divided into hard and soft coal. The former is unweathered at the outcrop and can be extracted in large pieces. But only one bed, a foot thick, has been discovered of this kind. The soft coal is broken and crumbly at the surface, but may improve at some depth. Such coal, however, would not be likely to admit of storage for any length of time without deterioration.

The following assays have been made to determine the composition:—

Seam.	Fixed carbon.	Volatile matter (exclusive of water).	Hygroscopic water.	Ash.	Caking properties.	Color of ash.
Tsetamá (sent by Mr. Savage).	43·5	28·8	8·4	19·3	Cakes very slightly.	Reddish gray.
6 feet seam, Tsetamá	38·4	28·9	14·6	18·1	Does not cake.	Light gray.
1 foot seam, Tsetamá	48·6	33·1	10·8	7·5	Cakes.	Red.
North-east of Pallang Roa	36·1	28·7	16·2	19·0	Does not cake.	Pale red.

The average composition of Rániganj coal, deduced from the assay of 31 samples, and of coal from the Sánktoria seam, which may be taken as a fair example of the best class of Rániganj coal, such as is supplied to sea-going steamers, is as follows[1]:—

	Fixed carbon.	Volatile matter (exclusive of water.)	Hygroscopic water.	Ash.
Average	53·20	25·83	4·80	16·17
Sánktoria	61·40	23·20	2·20	13·20

It will thus be seen that the Rámri coal is decidedly inferior to the Rániganj, and experience of nummulitic coal elsewhere shows that no marked improvement in composition can be hoped for at a greater depth from the surface.

The quantity of coal to be expected depends mainly on the thickness of the seams, their continuity and number. There is at least one known of sufficient thickness for convenient mining. With regard to their continuity, it would be hazardous to express any definite opinion. No natural sections are available by which any of the seams can be traced along the strike, and the attempt to do so by excavation would be a work involving a far greater expenditure of time and money than my instructions would have warranted. Disappointment has before now been experienced in Pegu in attempting to work similar coal, which on the original outcrop seemed to hold out good prospects of success, but which was

[1] Rec. G. S. I., vol. X, 156.

found on trial to die out rapidly.[1] On the other hand, the seams of nummulitic coal in Upper Assám have been traced in several cases for long distances. As for the number of the Rámri seams, there is of course a possibility of other beds being discovered, better perhaps than any at present known, but the natives of the locality, intimately acquainted with their jungles, say they possess no knowledge of any others than those described above. To search for outcrops at random in a country where the rocks are so obscurely seen, and without a map,[2] would be mere waste of time. But I think it may be predicted with some confidence that coal will not be found in anything like *abundance*. Where rocks are tilted up on edge, like those in question, any seams included in them must necessarily be cut through by streams running across the strike, and, in such cases, if the coal exists in any quantity, ample indications of its presence are generally afforded by the fragments, and often large lumps, washed down. But nothing of the kind is to be found amongst the shingle of the main streams near Tsetamá, which drain many square miles of country.

With reference to the extraction of the coal, the high inclinations of the seams would preclude quarrying on any but the most insignificant scale. The coal could only be raised in any quantity by mining, and mining in seams with such high and irregular dips would not be of the simplest kind.

Altogether, then, the prospect of successfully working the coal is not promising. Assuming, even, that the quantity is sufficient, the difficulty of mining it would necessitate a skilled European manager on a good salary, and to cover that expense a considerable quantity of coal must be raised. But the local demand is trifling, and beyond the sea, the mediocre quality of the coal and the expense of mining it, would, I am of opinion, prohibit its competing on even terms with the easily-mined and superior coal from Ràniganj. Sea-going steamers, with Bengal and English coal at command, would certainly not take such coal as that which has hitherto been found in Rámri, and I do not think it could be raised at such a price as to find a market even for local purposes at Akyáb.

Petroleum.

In the preceding paper I have alluded to the connection between the mud volcanoes and petroleum, and to the difference between the oils of Rámri and those of the Irrawádi valley. In as far as one can form any definite idea from mere description, the oil-bearing rocks in both regions would appear to bear considerable resemblance to each other,[3] and it has been stated by Mr. W. Theobald that they are certainly of the same geological age.[4] I think it can scarcely be doubted that the lignitiferous beds of Rámri and Cheduba are the true oil-producing as well as oil-bearing rocks.

In the Baránga Islands, however, although the oil is of the same character as that from Rámri, a marked difference is apparent in the rocks from which it issues. These are shales and sandstones of very constant character, without

[1] Selections from the Records of the Government of India (Home Department), No. X, p. 99.

[2] The revenue map does not even profess to mark the hills or streams.

[3] Mission to the Court of Ava, p. 312.

[4] Mem. G. S. I., X, 163.

the irregular calcareous nodules and nodular masses which are so generally characteristic of the beds in Rámri. I have never observed any appearance of either calcareous or carbonaceous matter amongst them. The shales are gray, brittle, sometimes slightly unctuous, often more or less arenaceous; they are frequently somewhat clunchy. The sandstone is generally gray or greenish-gray and tolerably fine grained, and is interbanded with the shale. The strike of the rocks is extremely regular, often running in a straight line for miles, and indeed varying little from end to end of the islands. The strata are thrown up at high inclinations, generally dipping at angles between 60 and 90 degrees. I am inclined to believe that the calcareous and lignitiferous rocks are rolled up with the above, and that it is from the former that the oil is originally derived in the Barángas as well as in Rámri. It is true that they do not appear in any part of the Barángas that I have visited, but my acquaintance with the islands is very limited,[1] and it is not impossible that, owing to less capability of withstanding denudation, they occupy the submarine areas between the islands. The similarity of the rocks in the three Barángas, and the observed dips, lend some little support to the idea that the Phadu and Chengdamma channels may mark the position of anticlinal bends with a synclinal between in the position of the middle island.

The digging of oil wells appears to have been carried on by the inhabitants of Rámri and Cheduba for a long time past, and at the present time such wells are worked in numerous localities. None of them, however, have been sunk to any great depth, and the scale on which the industry is conducted is comparatively trifling. It does not appear to be in the hands of any special class. About the end of December, or early in January, when the rice crop has been harvested, and the villagers have spare time on their hands, some of them take to well-digging as a means of adding to their income. The oil season lasts from that time till the rains, when the wells, which are most frequently sunk in, or close to, the bed of some nulla, get filled with water, and are often choked up entirely by debris washed into them.

The wells are of two classes—those which appear to be in communication with a natural reservoir, from which the oil, generally accompanied by large quantities of gas, rises with considerable rapidity, and those sunk in rock more or less soaked with petroleum from which the oil slowly exfiltrates into the well. The latter case imitates on a small scale the process which has been going on for ages on a large one in the case of the natural subterranean fissures.

To the former class would appear to belong the wells at Létaung near the western coast of Rámri. One of these is about 25 feet deep and 4 feet square. It is lined with wood throughout, so that the rock cannot be seen. At the bottom is water covered by a stratum of oil, through which a rather large quantity of gas bubbles up, chiefly from one corner of the well. The oil is drawn morning and evening, and the yield is said to be 15 bottles each time: much reliance, however, cannot be placed on figures supplied by the owners or lessees of the wells. Another well of the same kind, about 200 yards north-

[1] It is said that lignite has been found on the Eastern Baránga, but the exact locality is unknown.

west of the above, is about 40 feet deep, with water and oil at the bottom, which seems to boil gently from the issue of gas. The yield is said to be about 25 bottles twice a day. I was told that these wells have been in existence since the time of the Burmese domination, and that the yield of oil has not diminished. I am unable to say whether this statement is correct. The yield of oil, however, is only a few gallons a day, a quantity that a large reservoir, tapped only by a small duct leading to the bottom of the well, might supply for a very long period. The locality is worth notice. Close to the north-westerly of the above wells a new one was being sunk, in which the rock below the surface soil was a gray clay with a tendency of a peculiar kind of irregular flakiness. The strike cannot be seen, but to the north-east of the wells there is a ridge (doubtless as usual parallel to the strike of the beds composing it) running north-west—south-east, or parallel to the direction the wells bear to each other. It is noticeable that the clay from some wells that were being sunk last December at the village of Tsi Cháng (near Kyauk Phyu) was of a character similar to that at the Létaung wells, and that the oil was of a similar kind also, both in color (a pale yellow) and in specific gravity.

The not unfrequent fiery eruptions from one or other of the mud volcanoes occurring in a line near Tsi Cháng leave but little room for doubt that there is a fissure beneath them, in which large quantities of gas are generally stored up, and it is at least highly probable that a considerable quantity of oil is associated with the gas. A lucky boring might strike a spouting reservoir of great capacity, but of course such an undertaking would be of a speculative kind. There are no data to determine at what depth the oil is stored, nor what the inclination of the fissure may be, whether vertical or at a greater or less angle. A boring therefore sunk actually along the line of vents might miss it altogether. A few holes, however, sunk in a line at right angles to the line of vents, could hardly fail to strike it if sunk sufficiently deep. The experiment would certainly be an interesting one whether rewarded with success or not.

Gas is stored beneath the other active volcanoes also, but the linear arrangement of the Kyauk Phyu vents gives a better clue to the direction of the fissure than is obtainable elsewhere.

The wells in the southern part of the eastern Baránga, from which Mr. Savage has recently obtained such encouraging results, are evidently of the class now alluded to. They are sunk in gray shale which splits with a rather smooth fracture having a slightly unctuous feel. The bedding is very nearly vertical. It appears from the official correspondence on the subject that "Mr. Savage dug two wells about 500 feet apart, and then commenced boring. On the 25th February he struck oil in one well at a depth of 66 feet; the oil at once rose in the well .... to a height of four feet; it kept at this level for about seven days, and in that time yielded, Mr. Savage thinks, 1,000 gallons a day; since then the oil has remained in the bore-hole a few feet below the bottom of the well, and 120 gallons or more a day can be dipped out with a dipper. A great deal of the oil escaped from the well through fissures." "The well at its mouth was some 15 feet in diameter, and had been dug with those dimensions of a depth of some 30 feet. Here boring commenced, and had been

carried to a depth of 36 feet only, when the workmen were surprised and terrified by a sudden outburst of gas and oil, accompanied by loud subterraneous sounds, as of distant thunder. They had only time to make their escape up the ladders of the well before the oil and gas poured in in quantities that would otherwise have made their position a very perilous one." "Four days after Mr. Savage struck oil in the second well at a depth of 68 feet under similar circumstances, but the gas appeared stronger, making a great noise. About 150 gallons a day can be dipped out of this well.... The oil is clear and liquid; large quantities of gas continually escape not only in these wells, but in all other wells of small depth which are in the locality."

Of the second class of wells those near Minbain are amongst the most important. There are several scores of them, about a mile and a half north of the village, in an alluvial plain which is cut up by numerous nallas, which join and eventually drain into the Phultánu naddi. The wells are all sunk either in or close to the beds of the nallas, such being of course the lowest ground in the locality. They occur in groups of a dozen or twenty, the groups not being very far from each other (say one or two hundred yards), and the wells within a few feet or yards of each other. They are about 4 feet diameter, and vary in depth from 5 or 6 to 10 or 12 feet, and are all sunk in a rather tough grey clunch, which is generally covered by a foot or two of surface soil. In some wells the clunch towards the lower part is entirely soaked with petroleum, but more frequently the oil soaks the rock in patches, which have a darker color than the rock which is free from it. Although none of the wells are in communication with anything approaching the dignity of a fissure, there are evidently divisional planes and minute cracks which allow the oil to rise more freely in some spots than in others. At the bottom of the wells holes about 8 inches diameter and a foot deep are dug in the oleiferous patches of rock, in which the oil accumulates. It is collected twice a day; according to the sinkers, a good well will sometimes yield 4 or 5 bottles twice during the first day, but the yield rapidly diminishes. A few wells are failures, and yield no oil. One of the head men of Minbain, who was engaged in the well-digging, informed me that they are worked from about the beginning of December till the commencement of the wet season. The wells being mostly in the beds of nallas, of course get filled with rubbish every rains, but, as the yield diminishes so much with age, the diggers do not mind this, and open others in fresh spots every year. The annual yield is said to be about a thousand rupees worth of oil of late years. It is sold at six bottles per rupee. The total, therefore, would be 6,000 bottles or about 1,000 gallons.

In the ridge which stretches along the sea coast from Likmau to Minbain, the strata have a dip throughout to south-west. The dip is very obscure in the ridge between the wells and Thengchaung, and it does not seem to be regular, but I observed some apparent indications of its having a general easterly tendency. If this be the case, the oil-bearing rocks near Minbain are probably at or near the axis of an anticlinal bend, a position which in many oil regions (some of those in America and Japan for instance) has been found a most favourable one for well-sinking. The present wells, as will have been seen, have merely grubbed at the surface.

A mile or so north-west of Kangautau, there are a dozen or so of oil wells in the bed of a nalla of the same character as those at Minbain. They are sunk in a gray, more or less argillaceous sand (disintegrated sandstone?), some being lined with bamboo wickerwork. They were first opened last year. The best well, as I was told, yielded eight or ten bottles of oil the first day, but the yield rapidly diminished.[1]

The following table contains as complete a list as I have been able to make of the localities in the Rámri group of Islands and the Barángas, where oil has been obtained or indications of it observed. With reference to the Barángas it should be remarked that the results given are, with the exception of those connected with Mr. Savage's wells, those obtained up to the time of my visit. Boring operations had, however, then only just commenced, so that the small quantities of oil mentioned cannot in themselves be taken as any evidence of a scanty supply.

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[1] Captain Halsted states that in Cheduba oil is collected by turning up the soil, where oleiferous, to a depth of 2 feet, and surrounding it by a bank of earth, so as to form a shallow pond during the rains, about 20 yards square; gas and oil rise through the water, the latter of which is skimmed off and collected. (J. A. S., B., X, 369). This crude method was not practised in any of the oil-bearing localities I visited.

Locality.	Character of wells.	Rock in which wells are sunk.	Number of wells.	Depth in feet.	Stated daily yield in bottles.[1]	Color of oil by transmitted light.[2]	Specific gravity of oil at 62° F.
Rámri.							
Tsi Cháng .	Three wells were being sunk in December. Two were only a few feet deep: the third was 20 feet, and had struck oil in small quantity.	Gray clay with sandy and earthy calcareous nodules.	3	20	½	Transparent; color of brandy.	·809
Likmau .	Well full of water in December; the rice crop was being harvested and oil collecting had not commenced. Indications of petroleum occur in three other spots near the village. One of these is on the beach, where a shallow well has been sunk which has yielded a little oil.	Sandstone? .	2	About 18	3		
Minbain .	See above	Gray clunch .	Several score	5 to 12	0 to 8 or 10	Opaque; reddish brown in thin layers.	·867
Káugautau .	See above	Gray argillaceous sand (disintegrated sandstone?)	12—15	5 to 12	0 to 8 or 10	Transparent; color of sherry.	·839
Kyauk Galé .	Several pits about 100 yards from the shore on raised beach; they are from a few feet to as many yards diameter and one to two yards deep. Early in January they were filled to within two feet of the top with water, through which gas rose in some of the pits, and there was a faint smell of petroleum. According to the Tehsildár of Konboung, when these pits are emptied of water and dug out to some 15 cubits, they yield some oil. During the rains they get filled up with mud, &c.	Gray clunchy shales.	5 or 6	3 to 6	½, 1 and 4		

Létaung	See above	Gray clay	2 ?	...	...	Transparent; pale yellow.	·812
	No. 1	...	...	About 25 to surface of oil.	About 30		
	No. 2	...	...	About 40 to ditto.	„ 50		
Cheduba.							
¾ mile south-west of Kanthao Rea.	Wells said to have been first opened about four years ago; they are sunk near the bed of a nalla.	Superficial deposit of clay with rounded stones; the rock beneath is probably gray shale.	6—8. At times, it is said, there have been as many as 30.	10 and less	1 on an average.		
1½ mile west of Cheduba Town.	Mentioned by Captain Halsted (J. A. S., B., X, 369, 446). It had been destroyed by fire previous to 1841, but the soil around it was "full of the oil."	...	...	...	0 (1841)		
5½ miles north of Pagoda Hill.	Two wells not far from each other (Captain Halsted.)	...	2	...	60 pots each annually (1841).		
Near north point of Island.	Some shallow wells on sea beach.						
North-west of Kama.							
3 miles south-east of Pagoda Hill. At Kaindi Roa.	Mentioned by Captain Halsted. One of these is said to have yielded nearly 200 pots of oil annually, but it is not clear which is alluded to.	...	...	...	Nearly 200 pots annually (1841).		
Round Island.							
	There is a spot near the centre of the hilly ground on Round Island, where a smell of petroleum is perceptible in hot weather.						

[1] These figures, in as far as the Rámri group of islands are concerned, are not very reliable.
[2] In cylindrical bottles of 2¼ inches internal diameter. All the oils are dichroic.

Locality.	Character of wells.	Rock in which wells are sunk.	Number of wells.	Depth in feet.	Stated daily yield in bottles.	Color of oil by transmitted light.	Specific gravity of oil at 62° F.
Flat Island.							
Less than ½ mile south-east of volcanoes.	Several pits nearly filled with water in January; gas rises rather copiously from some of them, accompanied by oil.	.	About 6	3 or 4	About 1		
About 1 mile south-south-east of volcanoes.	Pits similar to the above . . .	..	2 or 3	3 or 4	About 1		
Baránga Islands.							
East Baránga: west of Khamang-doeh H. S.	Boring (in progress) on spot where an issue of gas had been observed.	Gray micaceous arenaceous shale.	1	70	0		
Upper part of Ahongjukhi naddi.	Pit in the bed of the nalla. A bottle or two only of oil was obtained, and the pit then abandoned. It is now filled with water, covered by a slight scum of oil; the rock in spots on the brink is impregnated with petroleum.	Gray rather fine-grained sand-stone.	1	9			
A little south of Raung naddi.	Mr. Savage's wells and borings mentioned above	Gray shale	3	.	...	Transparent; red.	·835
	No. 1	..	.	66	1,000 gallons a day during first week. Later on 120 gallons a day.		
	No. 2	...		68	150 gallons a day.		

	No. 3.—A well opened previously to the above, which has fallen in, and is now abandoned.			10 or 12	About ½ *man* every 3 or 4 days.		
On sea-beach between Raung and Prukhach naddis.	Several shallow pits, which at spring tide are filled with water, through which gas with a little oil rises. At neap tides small quantities of oil are obtained from them.	Grey arenaceous micaceous shale.	12 or more	3 to 6			
North bank of Prukhach naddi.	A pit a few feet deep was sunk in sandstone showing stains of oil. Only a trifling quantity was obtained.	Sandstone.					
Middle Barânga: north point of island.	Artificial pool through which gas with a little oil rises.	Shale and sandstone.	1				
20 or 30 yards south-east of above pool.	Boring (in progress) on Mr. Dawson's grant .	Ditto	1	76	0		
About ¼ mile from shore, 1½ miles north-west of Khiweroa.	Small pool through which gas rises. It is said there are other similar pools in the neighbourhood.	Gray clunchy shale?	1				
200 yards east-north-east of Khiweroa.	Several pools similar to the above. There is a small mud cone here a few yards in diameter, and with a slope of about 15°. The crater is filled with muddy water through which bubbles of gas rise. As the cone is situated in the bed of a nalla, it is washed away every rains.	...	4 or 5				
Western Barânga: ½ mile south-west of Mraingu.	Two borings (in progress) on Mr. Dawson's grant.	Alluvium with shale? below.	2	..	...	Transparent; color of dark sherry.	·879
	No. 1 . . .	..		50	3		
	No. 2	.	...	24	1		

Locality.	Character of wells	Rock in which wells are sunk.	Number of wells.	Depth in feet	Stated daily yield in bottles.	Color of oil by transmitted light.	Specific gravity of oil at 62° F.
	50 yards to the south of the borings, amidst some rice fields. there is a spot where gas rises, which shows itself during the rains by bubbles A little saline water issues with the gas, and, owing to the salt, there is a space of some yards around where rice will not grow.						
East coast near south end of island.	Indications of petroleum in three spots at least.						
Krinkwaimau Hills.							
Nagadweng	This name is applied to a natural pool a few yards diameter filled with muddy water, with mud below into which a 15-foot stick can be thrust to the end without difficulty. Gas rises in certain spots in some quantity, and the villagers say that occasionally it is given off in much greater amount.		1				
About 250 yards north-west of the above.	Artificial pit partially filled with water, through which some gas and a little petroleum rises.		1				
About 70 yards south of above pit.	Bore hole (in progress)		1	32	0		
Near Prairoa	About 1½ miles west of Nagádweng, near the village of Prairoa, there is said to be a pool of the same kind as that at Nagádweng, but of smaller dimensions.						

Limestone.

Limestone is very plentiful in Rámri. One of the most important localities is just north of the Yánthek creek, about two miles north of the village of the same name. The rock there is yellowish-white or occasionally reddish. It is rather brittle, and generally has a tolerably smooth fracture. Some parts have a fine granular structure. It includes strings and seams of calcspar, which weather out prominently from the mass of the rock, but it is free from chert and from interbedded layers of other rock. The bedding is generally obscure, and masses 20 feet thick occur in which none is apparent. In places, however, the rock has a slight tendency to flagginess. The dip and strike seem to be very inconstant. The supply is unlimited. I myself saw the stone to be continuous over an area of many acres, forming rocky hillocks 20 to 40 feet high, and the villagers with me said that it extends over an area four kos in circuit. The limestone is situated close to a tidal creek which joins the Yánthek creek within 200 yards, so that there is great facility for exportation.

The analysis of a carefully chosen average sample, made up of pieces from several of the small native quarries, yielded—

Calcium carbonate	94·4
Magnesium carbonate	·5
Ferrous carbonate (with some Fe_2O_3 & Al_2O_3)	1·5
Insoluble (mostly clay)	3·6
	100·0

The manufacture of lime is carried on in the neighbourhood, but not on any large scale. The rock is quarried with crowbars and hammers, having been previously heated by brushwood fires: gunpowder is not used. The kilns in which it is burned are circular, about 8 feet in diameter at the top and rather more at the bottom, with a depth of about 10 feet. They are dug out on a steep clay-bank, and have one orifice in front at the bottom about 18 inches diameter. There is a low clay wall round the top.

The lower part of the kiln is filled with logs of wood and the upper with broken stone in pieces up to some inches diameter. After some days, when the fire has burned out, the top portion of the stone, which is only partially burned, is removed separately, and the lime then withdrawn and slaked. Salt water from the creek is used for this purpose, as being the nearest at hand, but it is by no means calculated to improve the lime. The half-burned stone is added to the next firing. The slaked lime is sold at the kilns at the rate of twenty rupees per hundred *mans* (maunds).

Limestone of a very similar character to that at Yánthek also occurs in large quantity near Tsinbok. It is a yellowish-white rock looking like indurated chalk. Besides veins of calcspar it contains an occasional nodule of chert, which I have not observed in the rock at Yánthek. There are at least two outcrops to the south-west of the village, at one of which the limestone forms a hillock 30 feet high. From this alone a very large supply could be obtained, and it is within less than a mile and a half of a tidal creek. The composition of the stone is very similar to that of the Yánthek rock.

Between Tsetamá and Kyauk Tyán a different kind of limestone (p. 192) occurs in practically unlimited quantity. It is remarkable as being an almost pure carbonate of lime, there being hardly any matter in it insoluble in acid, and only traces of iron and magnesia.

Limestone also occurs, although in less abundance, at Thán Chaung, Tengbain, Allé Chaung, Tsáné, and Amherst Island. Doubtless it is to be found on Cheduba also. In the Baránga Islands, however, I observed no calcareous rock anywhere.

Besides true limestone, recent coral, owing to the elevation that the Rámri group of islands underwent during the last century (p. 190), occurs in large quantity along the coast in many places, where there are rocks that afforded the coral animals a secure foundation to build on. Amongst other localities may be mentioned the rocky point west of Kyauk Phyu and the similar point at Likmas.

It will thus be seen that there is an exhaustless supply of lime in the islands conveniently placed for export Mr. Theobald, also, mentions at least one spot on the coast of Arrakán to the south of Sandoway where limestone occurs in unlimited quantity and in a most favourable position with respect to shipment.[1] It is open to consideration whether the lime of Arrakán could not compete on paying terms in the Calcutta market with the Sylhet lime which is subject to the long and tedious river navigation from Chhátak.

Gypsum.

In some places, as at Kyauk Tyán and Amherst Island, there are gypseous shales through which crystals of selenite are sparsely disseminated These are to be found scattered about on the surface of the ground, owing to the weathering away of the rock. It would be difficult, however, to obtain more than a few sérs of them, and as a source of gypsum they are perfectly useless

Salt.

It appears from Dr Spry's paper on Kyauk Phyu written in 1841, that salt was at that time made there from sea water by solar evaporation, and sold by the people to Government at 7 annas a *man* [2] The manufacture has, however, been extinct for many years past.

Rock crystal.

Limpid rock crystals occur in some of the seams of the cherty rock mentioned at p. 192, and are collected sometimes by the villagers But they are too small to be of any commercial value

Alleged discovery of copper on Round Island.

In the twelfth volume of the Asiatic Society's Journal an account is given of an alleged discovery of native copper on Round Island. The specimens were found in 1843 by a Mug who was employed by Captain Williams to search for coal. Captain Williams sent them to Mr. Piddington, who pronounced them to be "nodules of native copper, with red and black oxide and silicate of copper.[3]" He also speaks of them as "rolled native (virgin) copper" "with a coating of red oxide and the blue and green carbonates.[4]"

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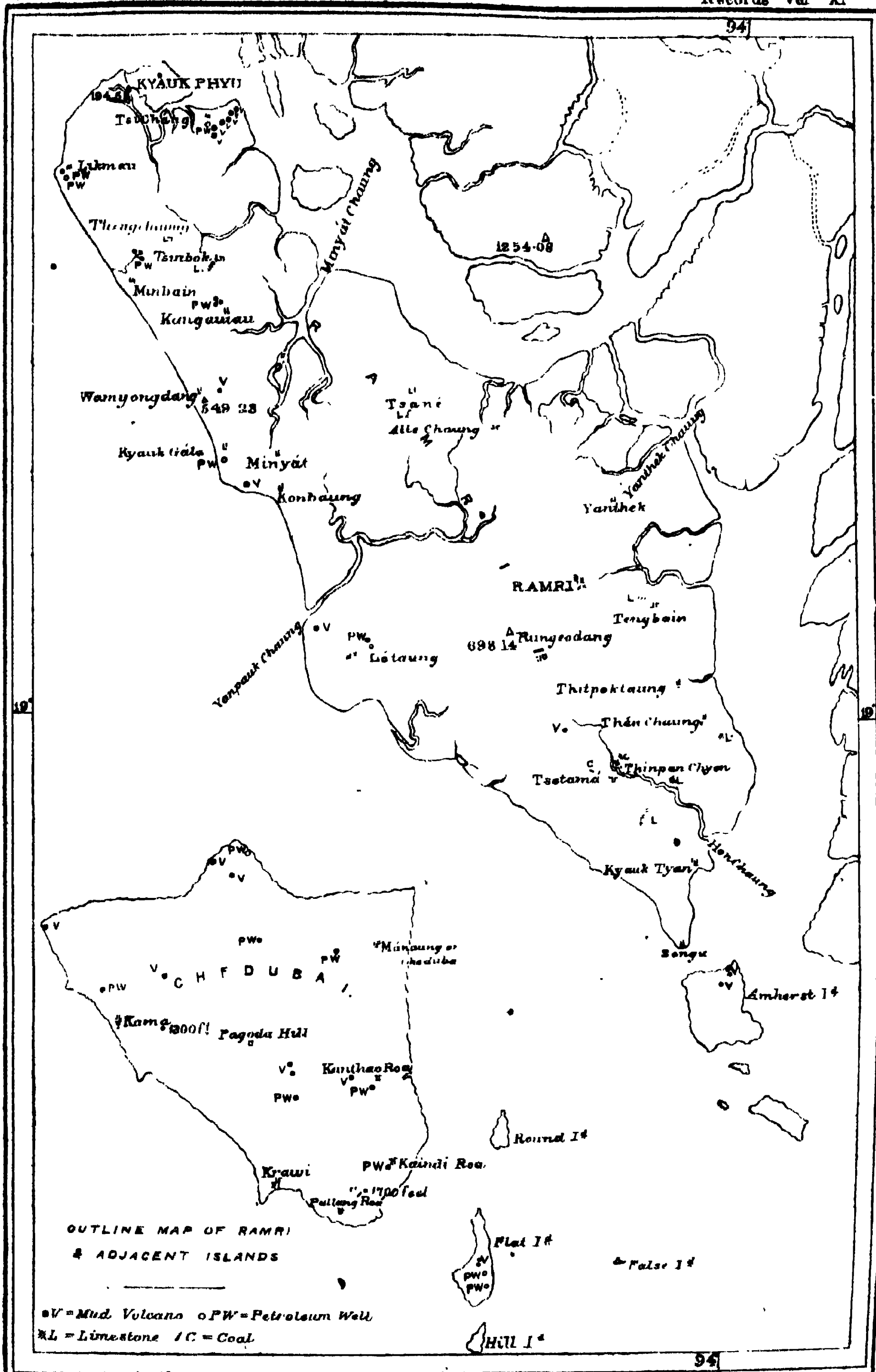
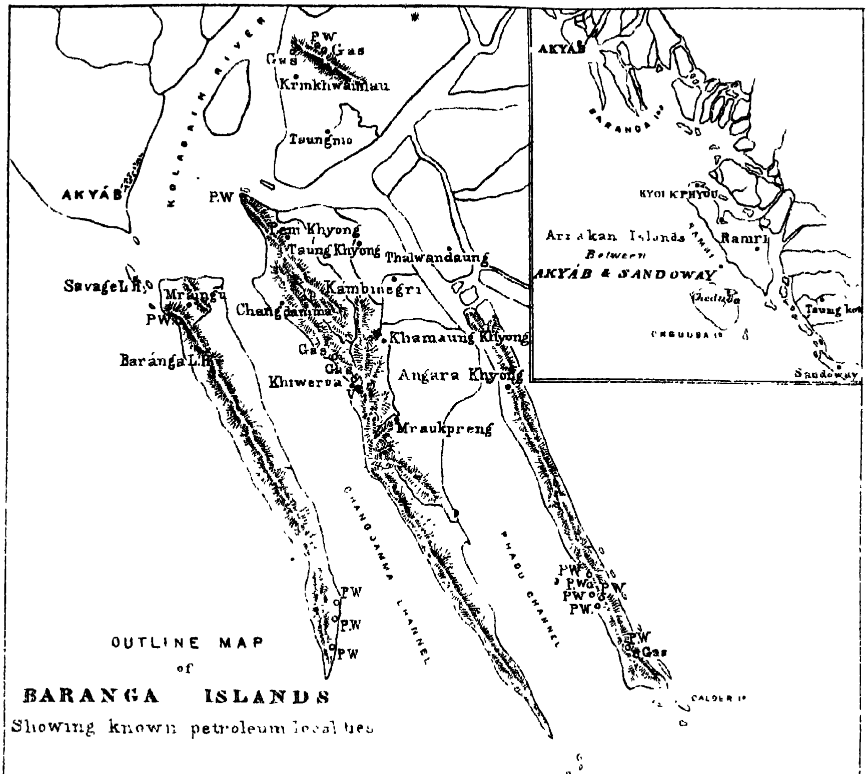
[1] Memoirs, X, 345.

[2] Journ. As. Soc., Bengal, X, 144.

[3] Journ. As. Soc., Bengal, XII, 333.

[4] Ibid, 914, 906. A very extraordinary analysis was given by Mr. S. Mornay, who considered specimens to be an alloy of copper, titanium, mercury, lead, cobalt and iron.


KYAUK PHYU
Tsochang
Likmau
Tsinbok
Minbain
Kungauuau
Minyat Chaung
Wamyongdang
549 23
Kyauk tiala
Minyat
Konbaung
Tsane
1254·08
Yanthek Chaung
Yanthek
RAMRI
Tengbain
Yenpauk Chaung
Letaung
698 14
Rungeodang
Thitpoktaung
Than Chaung
Thinpan Chyon
Tsetama
Kyauk Tyan
Hen Chaung
Songu
Amherst Id
C H E D U B A I.
Kama
1200 ft
Pagoda Hill
Kunthao Roa
Kaindi Roa
Krawi
1700 feet
Round Id
Flat Id
False Id
Hill Id
94
19°
OUTLINE MAP OF RAMRI
& ADJACENT ISLANDS
V = Mud Volcano   PW = Petroleum Well
L = Limestone   C = Coal



Isolated Rock on Sea-beach of Round Island. ⌒ – Present High tide level.

⌒⌒ = mass of recent marine shells six feet above ⌒

The locality seemed an unlikely one for copper to occur in, but before my visit to the island, the Deputy Commissioner, Mr. Duke, made enquiries on the subject, with, however, a negative result. Subsequently I went to Round Island, and found the hilly ground there to consist, as was anticipated, of stratified rocks similar to those of Rámri and Cheduba, and therefore of presumably early tertiary age. The occurrence of copper in such rocks would be most unusual. No one that I questioned on the subject had ever heard of copper having been found in the island.

Not long ago whilst arranging the series of Indian copper ores in the Geological Museum, I lighted on a tray containing a number of very irregularly shaped pellets from the size of a grain of shot to that of a large pea or more. They were composed of bronze-colored metal with a coating of red and black oxides and green carbonate of copper and with a few rolled grains of quartzose sand adhering to them. The accompanying label ran "Copper ore from Flat Island[1] off the south-east end of Rámri; presented by Captain Williams." On assay, the pellets were found to be an alloy of copper and tin, one which has never yet been found native, but which, artificially manufactured, is used to a considerable extent amongst the Burmese. It is clear therefore, that the metal found by the Mug was not native copper but artificial bronze, which, judging from the condition in which it was unearthed, had probably lain buried for a very long period.

ADDITIONS TO THE MUSEUM.

(FROM JANUARY TO MARCH 1878.)

Donors.

Burmese petroleum, and series of liquid and solid products manufactured therefrom.

THE RANGOON OIL COMPANY.

Specimens of zincblende from near Giridi; argentiferous galena from Phága (seven miles south-east of Danda, Bhágalpur District); and gray copper ore with barytes from Jabalpur District.

W. G. OLPHERTS, ESQ.

Copper pyrites in Kaladgi limestone (Madras Presidency).

DR. THORPE.

Two series of minerals (by exchange).

MINERAL DEPARTMENT, BRITISH MUSEUM.

SERIES I.

Aikinite in quartz, Beresowsk, Urals, Russia.

Anorthite, with biotite and pyroxene, Monte Somma, Vesuvius.

" var. Amphodelite, with pyroxene and copper pyrites, Tunaberg, Sweden.

[1] In the original papers in the Asiatic Journal there is a confusion between Round and Flat Islands—*Vide* p. 904.

Anthosiderite, Antonio Pereira, Pernambuco, Brazil.
Aeschynite in orthoclase, Ilmen Mountains, Orenburg, Russia.
Apatite, massive, Krageröe, Norway.
„ „ Lofthuus, Norway.
„ var. Phosphorite, Estramadura, Spain.
Arseniosiderite, Romanêche, Saone et Loire, France.
Alunite in crystals and massive, Tolfa, near Civita Vecchia, Rome.
„ massive, Bereghszasz, Hungary.
Aurichalcite, with calcite, Matlock, Derbyshire.
„ with wad, Monte Poni mines, Sardinia.
Berzelianite in calcite, Skrikerum mines, Småland, Sweden.
Boulangerite, with galena, Ober-Lahr, Rhine.
„ „ Sala, Sweden.
Beudantite in interstices in limonite, Montabaur, Nassau.
Biotite, with hornblende and augite, Monte Somma, Vesuvius.
„ from the granite of Lake Baikal, Irkutzk.
„ with muscovite and orthoclase, Ilmen Mountains, Orenburg, Russia.
Brochantite, with quartz and limonite, Roughten-Gill, Cumberland.
Covellite, with calcite and massive gersdorffite, Sangerhausen, Thuringia.
Calomel in crystals, with ochreous limonite on a micaceous sandstone, Moschellandsberg, Rhenish Bavaria.
Cotunnite on a scoriaceous leucite lava, Vesuvius.
Chiolite, Ilmen Mountains, Orenburg, Russia.
Chrysoberyl, with manganese-garnet, smoky quartz and albite, Haddam, Connecticut, U. S. A.
„ with garnet and mica in quartz, Marschendorf, Moravia.
Cervantite pseudomorphous after stibnite, with crystalline massive ditto, Borneo.
Crocidolite, Asbestos Mountains, Orange R., South Africa.
Cancrinite (yellow), with elæolite, mica and felspar, Marienskoi mine, Tunkinsker Mountains, Lake Baikal.
„ (pinkish), Ilmen Mountains, Orenburg, Russia.
Cronstedtite, with quartz, chalybite, copper pyrites, chlorite and mispickel, Cornwall (mine not yet ascertained).
„ with limonite in iron pyrites, ditto.
Chloritoid, with quartz on a gneissoid rock, Pregratten, Pusterthal, Tyrol.
Chamoisite, Chamoison, Wallis, Switzerland.
„ var. Berthierine, Bourgogne, France.
Clinoclase, with wad on quartz, St. Day, United Mines, Cornwall.
Coquimbite, with copiapite and chalcanthite, Copiapo, Coquimbo, Chili.
Domeykite, Copiapo, Chili.
„ var. Condurrite, with cuprite, Condurrow mine, near Redruth, Cornwall.
Dipyre, Vallée de Castellon, St. Giron, L'Ariège, France.
Dechenite, Freiburg, Baden.
Enargite in crystals, with copper pyrites in a silicious matrix, Parad, Tatra Mountains, Hungary.

Enargite crystalline massive, with copper pyrites in a silicious matrix, Parad, Tatra Mountains, Hungary.
Euphyllite, with tourmaline, Chester Co., Pennsylvania, U. S. A.
Euchroite, on mica-slate coated with ochreous limonite, Libethen, Hungary.
Epsomite, Calatayud, Aragon, Spain.
Ekmannite, Brunsjö iron mine, Arebrö Län, Grythytte, Sweden.
Fergusonite in quartz, with black mica and a little felspar, Ytterby, Sweden.
Fibroferrite, Copiapo, Chili.
Greenockite, with calcite and chlorite, near Bishoptown, Renfrewshire, Scotland.
Glaucodote, with copper pyrites, Hakansboda, Sweden.
Gearksutite, with chalybite in cryolite, Evigtok, Arksut-Fjörd, West Greenland.
Hessite or Petzite, Sawodinskoi mine, Altai.
Hydrotalcite, with serpentine, Snarum, Norway.
Herschelite, with phillipsite and mealy zeolite in cavities in a lava, Aci Castello, near Aci Reale, Sicily.
Hydrophite, with serpentine, Taberg, Wermland, Sweden.
Hjelmite in albite, Fahlun, Sweden.
Hatchettite, with chalybite, bitumen and quartz in cavities in clay iron-stone, Merthyr Tydvil, South Wales.
Jadeite, China.
Jefferisite, Westchester, Pennsylvania, U. S. A.
Knebelite, Dannemora, Sweden.
Killinite in granite, Killiney Bay, Co. Dublin, Ireland.
Karstenite, Schaffhausen, Rhine.
,, Gmünden, Austria.
,, with salt, Salzburg.
,, with hæmatite, Hall, Tyrol.
Lead (native), in granular hausmannite, Pajsberg iron mines, Philipstadt, Wermland, Sweden.
Levyne, with mesolite in cavities in a trap rock, Little Deer Park, Co. Antrim, Ireland.
Liroconite, with clinoclase, St. Day, United Mines, Cornwall.
Lanarkite, with leadhillite, caledonite, cerussite, and pyromorphite, Leadhills, Lanarkshire.
Minium, The Eifel, Rhenish Prussia.
Meliphanite, with mica and allanite in felspar, near Frederikswärn, Norway.
Mellilite, with pseudonepheline and apatite on dolerite, Capo di Bové, near Rome.
,, Monte Somma, Vesuvius.
Mosandrite, with black mica in zircon syenite, Langesund Fjörd, Brevig, Norway.
Megabasite, with fluor and molybdenite in quartz, Schlaggenwald, Bohemia.
Manganocalcite on quartz, Schemnitz, Hungary.
Nagyagite, with müllerite, and quartz, mingled with rhodochroisite, Nagyag, Transylvania.
,, in crystals, with quartz, blende, and rhodochroisite, ditto ditto.
Natron, Egypt.
Ozokerite, Gallicia, Poland.

Perofskite, with clinochlore in crystalline limestone, Achmatowsk, Urals.
Pyrochroite in magnetite, Pajsberg iron mines, Philipstadt, Wermland, Sweden.
Phenakite, with small crystals of quartz in an ochreous limonite, Frammont,

„ in bright crystals on an albitic granite, Ilmen Mountains, Orenburg, Russia.
Phenakite from the emerald mines of Ekaterinburg, Perm, Russia.
Pyrosmalite, with hornblende on magnetite, Nordsnarken, Wermland, Sweden.
„ with hornblende and chlorite on magnetite, ditto ditto ditto.
Penninite, partly encrusted with small crystals of garnet, Zermatt, Switzerland.
Prochlorite, with copper pyrites and quartz, Cornwall.
„ with dolomite on magnetite, Traversella, Piedmont.
„ var. Ogcoite, St. Gotthard, Switzerland.
Pharmacolite, with erythrite on carbonate of lime, with galena, Wittichen, Baden.
Predazzite, Predazzo, Tyrol.
Römerite, with copiapite and chalcanthite, Copiapo, Coquimbo, Chili.
Ratholite or Pectolite, Ratho quarry, near Edinburgh.
Retinasphalt, Bovey Tracey, Devonshire.
Sternbergite, Joachimsthal, Bohemia.
Sylvanite, with drusy quartz on a trachyte porphyry, Offenbanya, Transylvania.
„ var. Müllerite, with blende in a brecciated siliceous rock, Nagyag, Transylvania.
Sal Ammoniac in crystals on a scoriaceous dolerite lava, Vesuvius: Eruption, November 1868.
Sarcolite, with pyroxene, Monte Somma, Vesuvius.
Staurolite, with kyanite and mica in paragonite slate, Giornico, Levantino Valley, Tessin, Switzerland.
„ with garnet in mica-slate, Taganai, Urals.
Sapphirine, with mica, Fiskenaes, Greenland.
Schrötterite, Libethen, Hungary.
„ near Tavistock, Devonshire.
Scolecite, Berufjörd, Iceland.
Smectite, Kreuznach, Rhine.
Samarskite in granite, Ilmen Mountains, Orenburg, Russia.
Sordawalite, Sordawala, Finland.
Tallingite, with atacamite and wad, Botallack mine, St. Just, Cornwall.
Ullmannite, with chalybite and copper pyrites, Siegen, Prussia.
Ulexite in gypsum, Brookville, Hants Co., Nova Scotia.
Voigtite in graphic granite, Manebach, Thuringia.
Vauquelinite, with crocoisite, pyromorphite, cerussite pseudomorphous after galena, limonite pseudomorphous after iron pyrites, and quartz, Beresowsk, Urals.
Volborthite, with wad on Permian sandstone, Ivanow's copper mine, Perm, Russia.
„ on limonite, Sissersk, near Nijni Tagilsk, Perm, Russia.
Wehrlite, Szurraskö, Hungary.

Wöhlerite, with elœolite and cancrinite in zircon syenite, Langesund Fjörd, near Brevig, Norway.
Wagnerite, with brown-spar in a greenish clay-slate, Höllgraben, near Werfen, Salzburg.
Walchowite, Walchow, Moravia.
Xenotime, with yellow and black yttrotantalite in felspar, Ytterby, Sweden.
Zippeite, with small crystals of selenite, Wheal Edward, near St. Just, Cornwall.

SERIES II.

Albite, with malachite and chessylite, Kirabinsk Mine, Ekaterinburg, Russia.
Albite, with chalybite, Zillerthal, Tyrol.
Andalusite, Brazil.
Aragonite in twinned crystals, Bilin, Bohemia.
Arsenic (native), with calcite, Andreasberg, Hartz.
Avanturine quartz, Cape de gata, Spain.
Barytocalcite in crystals and massive, Alston, Cumberland.
Calcite in fascicular groups on quartz, with blende and galena, Schemnitz, Hungary.
Calcite on fluorspar, near Camborne, Cornwall.
Cadmiferous blende, Przibram, Bohemia.
Chesterlite in granular dolomite, Chester Co., Pennsylvania.
Chiastolite in clay-slate, Lancaster, Massachusetts.
Chrysolite in crystals, The Levant.
Corundum crystal, Tibet.
" " Salem, Madras.
Dolomite, columnar, with dendritic manganese oxide, Sunderland.
Fassaite in blue calcite, Fassa, Tyrol.
Fahlunite in talc slate, Fahlun, Sweden.
" " with copper pyrites, Fahlun, Sweden.
Felspar (compact), colored in spots with manganese oxide, Charlotte, North Carolina.
Fire opal, Zimapan, Mexico.
Green tourmaline, with sapphire in granular dolomite, Campolongo, St. Gotthard, Switzerland.
Grossular garnet, Fassathal, Tyrol.
Grossular in loose crystals, Wilui R., Trans-Baikal.
Gurhofite, Gurhof, Styria.
Humite, with biotite and calcite, Monte Somma.
Hyposclerite, with melanite, Arendal, Norway.
Leelite, with actinolite, Salberg, Sweden.
Limonite, fibrous and compact, Orkney Islands.
" Siegen, Prussia.
Mesolite, with thomsonite and stilbite, Renfrewshire.
Moonstone, Ceylon.
Murchisonite, Heavitree, near Exeter, Devon.

Natrolite, with analcime on basalt, Auvergne.
,, in a cavity in basalt, Leipa, Bohemia.
,, with gmelinite in trap rock, Co. Antrim.
,, on phonolite, near Aussig, Bohemia.
Omphacite, with garnet, San-Alpe, Carinthia.
Orthoclase (massive), Frederikswärn, Norway.
Petalite, with lepidolite, Island of Uto, Sweden.
,, with spots of indicolite, Island of Utö, Sweden
Physalite, Trumbull, Connecticut.
Prase, Breitenbrünn, Saxony.
Pyrolusite, coating stalactitic psilomelane, Thuringia.
,, Nassau.
Pyrophysalite in quartz, Finbo, Sweden.
Pyrophysalite, Finbo, near Fahlun, Sweden.
Pyroxene, with hornblende, Arendal, Norway.
Quartz, pseudomorphous after chalybite, Cook's kitchen mine, Cornwall.
Richterite, with schefferite and hematite, Langbanshyttan, Sweden.
Rubellite, with indicolite and green tourmaline, in albite, Chesterfield, Massachusetts.
,, Elba.
Sahlite, with galena and calcite, Sala, Sweden.
,, with hornblende and sphene, Arendal, Norway.
Schefferite, with rhodonite, Langbanshyttan, Wermland, Sweden.
Siliceous sinter, The Geysers, Iceland.
Spinel (blue), with hornblende and mica in limestone, Aker, Sweden
Tasmanite, Mersey R., North Tasmania.
Topazolite, with mussite, Mussa, Piedmont.
Wood-tin, near Truro, Cornwall.
,, in water-worn fragments, Cornwall

ADDITIONS TO THE LIBRARY.

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BRUSH, GEO. J.—Appendices I and II to the 5th Edition of Dana's Mineralogy (1872), 8vo, New York.

CUNNINGHAM, ALEX.—Corpus Inscriptionum Indicarum, Vol. I—Inscriptions of Asoka (1877), 4to, Calcutta.
HOME DEPARTMENT.

ELLIOTT, SIR H. M.—History of India, Vol. VIII, (1877), 8vo, London.
HOME DEPARTMENT.

ENCYCLOPÆDIA BRITANNICA, Vol. VII, 9th Edition (1877), 4to, London.

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DEPARTMENT REVENUE, AGRICULTURE AND COMMERCE.

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THE AUTHOR.

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THE AUTHOR.

PERIODICALS, SERIALS, &c.

American Journal of Science and Arts, 3rd Series, Vol. XIV, Nos. 83-84 (1877), 8vo, New Haven.
THE EDITORS.

Annalen der Physik und Chemie, New Series, Vol. II, heft 3-4, and III, heft 1 (1877-78), 8vo, Leipzig.

Annales des Mines, 7th Series, Vol. II, livr. 5; V, livr. 3; IX, livr. 1; XII, livr. 5 (1872, 1874, 1876-77), 8vo, Paris.
L'ADMINS. DES MINES.

Annals and Magazine of Natural History, 4th Series, Vol. XX, No. 120, and 5th Series, Vol. I, Nos. 1-2 (1877-78), 8vo, London.

Archiv für Naturgeschichte, Jahrg. XLIII, heft 4, and XLIV, heft. 1 (1877-78), 8vo, Berlin.

Athenæum, Nos. 2616 to 2620, and 2622-2627 (1877-78), 4to, London.

Bibliothèque Universelle et Revue Suisse, New Series, Vol. LX, Nos. 239-240 (1877), 8vo, Lausanne.

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Colliery Guardian, Vol. XXXIV, Nos. 884-889 and 891-896 (1877-78), fol., London.

Geographical Magazine, Vol. V, No. 2, (1878), royal 8vo, London.

Geological Magazine, New Series, Decade II, Vol. IV, No. 12, and V, Nos. 1-2 (1877-78), 8vo, London.

Journal de Conchyliologie, 3rd Series, Vol. XVII, No. 4 (1877), 8vo, Paris.

London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 5th Series, Vol. IV, Nos. 27-29 (1877-78), 8vo, London.

Mining Journal, with Supplement, Vol. XLVII, Nos. 2207-2212 and 2214-2218 (1877-78), fol., London.

Nature, Vol. XVI, Nos. 423-428 and 430-435 (1877-78), 4to., London.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, Jahrg. 1877, heft 9, and 1878, heft 1 (1877-78), 8vo, Stuttgart.

PETERMANN, DR. A.—Geographische Mittheilungen, Band XXIII, No. 12, and XXIV, Nos. 1-3 (1877-78), 4to, Gotha.

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Reports of the Mining Surveyors and Registrars for quarter ending 30th September 1877 (1877), flsc., Melbourne.

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Zeitschrift der Deutschen Geologischen Gesellschaft, Band XXIX heft 3 (1877), 8vo, Berlin.

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„ Journal of the Asiatic Society of Bengal, New Series, Vol. XLVI, Part 1, Nos. 3-4 (1877), 8vo, Calcutta.

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LONDON.—Palæontographical Society's Publications, Vols. XIX (1865), XX (1866), XXV (1871) to XXXI (1877), and Part 2 of 1849, 4to, London.

„ Philosophical Transactions of the Royal Society of London, Vol. 166, Part 2, and 167, Part 1 (1877), 4to, London.

THE SOCIETY.

„ Quarterly Journal of the Geological Society of London, Vol. XXXIII, Part IV, No. 132, with list of Fellows for 1877 (1877), 8vo., London.

DITTO.

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THE ASSOCIATION.

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" Bollettino R. Comitato Geologico d'Italia, Nos. 11-12 (1877), 8vo, Rome.

THE GEOLOGICAL COMMISSION.

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" Kongliga Svenska Vetenskaps-Akademiens Handlingar, Vols. XIII and XIV, Part 1 (1875-76), 4to, Stockholm.

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„ Bollettino dell' Osservatorio della regia Università di Torino, Anno XI (1877), 4to, Turin.

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THE INSTITUTE.

„ Ninth Annual Report of the United States Geological and Geographical Survey of the Territories embracing Colorado and adjacent territory for 1875 (1877), 8vo, Washington.

THE SURVEY.

„ Preliminary Report of the Field work of the United States Geological and Geographical Survey of the Territories for season of 1877 (1877), 8vo, Washington.

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YOKOHAMA.—Mittheilungen der Deutschen Gesellschaft für Natur und Völkerkunde Ostasiens, heft XIII (1877), fisc., Yokohama.

THE SOCIETY.

April 24th, 1878.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] **1878.** **[February.**

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1877.

New ground.—The field-work of the Geological Survey of India is of two kinds: the preliminary exploration of ground regarding which our knowledge is either a blank or exceedingly vague, and the more detailed study of rocks the general features of which have been laid down. The latter is essentially the more difficult task, and, within certain limits, the more interesting to the geologist, as requiring the more exact application of the guiding principles of his science, and as affording the better opportunity of testing and defining those principles themselves. The attractions of the former, both to the worker and the looker-on, are its rapidity and the more easy attainment of the sensation of adding something to our store of knowledge. In the progress of the Survey, the proportions of these two kinds of work undergo a constant change; but we are still far from the state of having no new ground to explore. During the past season two such blanks have been approximately filled in.

I am glad to announce that the principal of these reclaimed territories is in the higher Himalaya. Hitherto our work in this most interesting region has been in a manner occasional. The circumstance of my connection with the College at Roorkee for some years placed me within easy reach of the lower Himalaya, and the results of four seasons' work were published in 1864 (Memoirs, G. S. I., vol. III). Dr. Stoliczka's zeal for great undertakings led him early to urge the exploration of Western Tibet. The result of his observations in that difficult region during the summers of 1864 and 1865 were published in vol. V of our Memoirs, and were supplemented by his notes on his last fatal journey to Kashgar in 1873 (Records, G. S. I., vol. VII). The urgent demand for coal in connexion with the Northern Bengal Railway led to Mr. Mallet's deputation in 1873 to examine the Damúda rocks discovered in 1849 by Dr. Hooker at the base of the Sikkim Himalaya. Mr. Mallet's observations on this fringe of the mountain region were published in vol. XI of the Memoirs. The foregoing accounts, together with the observations by Captain R. Strachey, R.E., in Kumaun and Central Tibet, and published with a map in the Quarterly Journal

of the Geological Society, London, vols. VII and X (1851 and 1854), constituted so far the only definite materials for a geological map of the mighty Himalaya. In 1875-76 the examination of the outer tertiary zone and adjoining rocks was carried up to the Jhelum (Records, vol. IX); and in continuation of this work, Mr. Lydekker, during the past season, has made an extensive exploration of the mountains north and south of the Kashmir Valley and in the upper basin of the Chenáb.

That so little should have been known regarding the geology of such an attractive spot of earth as Kashmir, is a fair indication of the difficulty of the ground. Flying observations have of course been recorded, and some bold speculations based thereon; but these contribute little towards a definite knowledge of the rock-structure. The presence of carboniferous strata was long since observed, and the extensive occurrence of eruptive rocks has been prominently noticed; but the relations of all these to the preponderating mass of contiguous unfossiliferous rocks have remained unknown. Mr. Lydekker shews that the Kashmir area is a compressed synclinal ellipse, on the pattern of the larger features defined by Stoliczka in the Tibetan region, but containing, so far as observed, no rocks younger than the trias. The slates of the Pir Panjál are shewn by connected observations to be the equivalents of the Silurian and *infra*-Silurian strata of the Tibetan sections. After some hesitation, Mr. Lydekker decided that the trappean rocks must belong to a period of local eruption in the upper part of the Silurian series. Although very frequently observed in abrupt and troubled contact with the carboniferous rocks, they were never seen to penetrate these strata, or above them.

On the south-eastern prolongation of the Kashmir synclinal, but separated from it by a mass of metamorphic rocks in Kistwár and Badriwár, there is in the Pángi district, on the upper Chenáb, a smaller synclinal ellipse, in which only the Silurian slates have been found. This basin is cut off to the south-east by the gneissic masses of Lahul. This feature of longitudinal structure—the recurrence of basins of depression along the same mountain zone—is also a character of the more central Himalayan regions, where the great basin of Spiti and Zanskar is cut off from the very similar basin of Hundes, on the same strike, by the metamorphics of North Bisáhir. The fact seems to preclude the suggestion that has been made, that these basins are in some degree aboriginal with relation to the included formations.

The relations of the gneissic series are still the most obscure point in these mountain-sections. Mr. Lydekker feels compelled to adopt the view that the Pir Panjál range is, on the whole, a great folded anticlinal flexure, having a core or axis of gneiss, the whole stratified series on the outer (south-west) side being inverted. In this arrangement, if the gneiss is even approximately conformable with the slate series (as this view implies and as is apparently the case), the actual position and structure of this gneiss and of the contiguous slates must be due to acts of disturbance common to both; for, it would seem impossible to produce the great fold, and the inversion of the strata on the south-west, if the gneiss had pre-existed as a ridge in this position. Again, there are clear sections shewing the slate series to pass transitionally (by interstratification)

downwards into crystalline schist and gneiss, which certainly implies that the conversion of this gneiss is of later date than the deposition of the slates. Yet there are observations in this region shewing most indubitably that, during the deposition of the slates, a gneiss was undergoing violent denudation, and at no great distance: throughout a considerable thickness of strata in Pángi, large blocks of gneiss are imbedded in the unaltered slates. From the circumstances Mr. Lydekker conjectures that they were ice-borne; but, however this may be, the immediate difficulty is, that they seem to be of Himalayan gneiss, as they resemble it, and are not like any known gneiss of the nearest region to the south. If they were derived from any gneiss now exposed in the Himalaya, we may surely say that it must be of very different age from the gneiss conformably underlying and transitional with these same slates; and that the unconformity between the two series must, at least originally, have been of a very striking character, so that the non-recognition of such a feature would vitiate any independent interpretation of the rock-structure. The question radically affects the view to be taken of the mountain-formation; but we are still in uncertainty regarding it, no such distinction having been as yet detected in the gneissic masses of this region. The great gneissic mass of the Zanskar range is certainly to some extent composed of a gneiss associated with the slates; the so-called "central gneiss" has also been provisionally identified in it; but no mineralogical criterion or stratigraphical demarcation has as yet been attempted between them. An account of Mr. Lydekker's observations is published, with a skeleton map, in the current number of the Records.

In this connection I am glad to have to notice the work of a geologist who is not on the staff of the Survey, although his observations have been published in our Records for the past year. Workers for love of geology have become so rare in India that the appearance of one is quite an event; and Colonel McMahon's paper is in good form, representing much hard work in the field and the study, put together rationally, without random speculation. His map of the Simla region indicates a clue to the structure of the most difficult region of Himalayan geology, and an interpretation that may prove of great service is suggested. The ground sketched by Mr. Lydekker, although adjoining the great fringing zone of tertiary rocks, is strictly on the prolongation of the great central Himalayan range, and the structure is on a reduced scale of the same type. The Simla region is quite different: it belongs to that broad area of lower mountains which to the east of the Satlej separates the snowy range from the plains, and is made up of metamorphic and slaty rocks in a very irregular and incomprehensible mode of distribution. In the midst of the slate series there is one well-marked group, affording the most certain guide to the disturbance of the strata. Colonel McMahon has mapped its outcrop over an extensive tract of rugged mountains. He has also indicated for this region a probable solution of the difficulty noted in Mr. Lydekker's work regarding the gneissic rocks. He shews that the massive gneiss forming several prominent ridges in the lower mountains must be the same as the "central gneiss" of the main range; he describes the upper members of the slate series to be so related to this gneiss as *to* involve

the total overlap of the lower part of the series, and therefore complete unconformity to the gneiss; subsequent metamorphic action, largely affecting the slate series itself, especially at the contact with the older gneiss, has so obscured the junction as to make the exact definition of it a matter of great difficulty.

The other newly reclaimed area is in Peninsular India. The wide tract (some 300 miles long) between the Máhanadi and the lower reaches of the Godávari, although completely surveyed topographically, is one of the least frequented regions of the Peninsula. It is a wild hilly country entirely occupied by primitive tribes and petty tributary states. From the condition of adjoining areas we could only conjecture that it was occupied by Vindhyan and gneissic rocks; and such has proved to be the case. During the past season, Mr. Ball made an extensive circuit over that ground, and an account of his observations has already been published, with a sketch-map, in the Records.

On the coast side there is a broad mountainous belt (130 miles wide), some summits exceeding 5,000 feet in elevation. It is known on both sides to be formed of crystalline rocks, and is probably so throughout. West of this there is an extensive upland, also largely formed of gneissic rocks, but upon which there stand two or more scarped plateaus of flatty bedded sandstone, the principal being that of Nowagarh-Khariál. Further west there is the wide expanse of lower ground formed of the shales, limestone and sandstones, occupying the plains of Chhattisgarh and the upper valley of the Máhánadi, and stretching southwards to the more elevated land about Bastar. These latter rocks have for long been recognised as of lower Vindhyan age; but Mr. Ball thinks that the Khariál sandstones may represent upper Vindhyans, as they are locally underlaid by shales very like those of the Chhattisgarh plains. As yet no upper Vindhyans have been identified south of the Son-Narbada valley. That these formations should still have to be classed as azoic, is a recurring cause of surprise and disappointment to geologists in India.

In the valley of the Tel and elsewhere in low ground south of the Máhánadi, Mr. Ball observed several distant outliers of the Talchir deposits; while on the highest summits visited, both of detached hills and within the range of the Eastern Ghâts, he found the massive rock-laterite, giving a plateau character to the otherwise serrated mountain-features. This high-level laterite forms, throughout the whole of middle and northern India, a thick (50 to 100 feet) level capping to most of the highest summits, whatever may be the structure of the underlying rocks, and has the same composition, whatever may be that of the rocks it rest upon, so that it cannot in any way be derived from their transformation. Its mode of origin is still one of the greatest puzzles in Indian Geology.

During a short visit to Naini Tal in September, Mr. Ball made some observations regarding the numerous lakes of that neighbourhood.

Mr. Hacket's work in Rajputana must also rank as in new ground. He has carried his observations to some distance south of Ajmir, where he obtained a fuller section of the metamorphic rocks transitionally underlying his Arvali series. In the northern sections, about Alwar and Biána, these transition beds

seem to be locally wanting. Altogether the study of these highly altered and disturbed formations is most intricate, and it is likely to be long before a connected and satisfactory account of them can be given.

Mr. Hacket confirmed in other localities Mr. Blanford's discovery of Vindhyan strata to the west of the Arvali range, but in a more easterly position, resting quite flatly close to the main series of gneissic rocks; so that the Vindhyan formation must be altogether younger than the Arvali mountain-system.

No rocks but the quartzites and other strata of the Arvali series were found in the vicinity of the famous Sámbhar salt-lake; and no observation was made suggesting any connection of the salt with these rocks.

Gondwána formation.—The recognition of the Karharbári coal-measures as a distinguishable horizon in the lower Gondwána series is an interesting step in our knowledge of these formations. As immediately overlying the Talchírs, these beds have hitherto passed as belonging to the Barákar group, the lowest of the Damuda coal-measures. The first discovery in them of peculiarly triassic plants not found elsewhere, looked at from the point of view of palæozoic affinities for the Damuda flora, suggested that the Karharbári beds should be regarded as above the Damudas. Further collections of fossils made by Dr. Feistmantel, and others presented by Mr. Whitty, the engineer in charge of the extensive mines from which the East Indian Railway is supplied, have not supported this notion. Dr. Feistmantel points out that with those special plants are found the few which most distinguish the Talchirs, and that the affinity is with this bottom group of the Gondwána system, rather than with the Damudas. The position of the field, well out of the Damuda valley, and more analogous to that of the central fields, in which also the coal-measures have hitherto been regarded as Barakár, suggests that these too may be found to present these new palæontological affinities. Dr. Feistmantel reports from Mohpáni that there is some confirmation of this view in the plants he has recently found there. The very close stratigraphical relations of the Satpura coal-measures with the Talchirs in the Betúl field was insisted upon in the last survey of that ground (Records, vol. VIII, p. 65, 1875).

Of our detailed work an interesting area of the Gondwána formations was completed during last season by Mr. Hughes, in extension of his previous work in the Wardha valley, the geological lines being now carried down to the Godávari at and above Sironcha. An important practical result of this work is the accurate demarcation of a considerable area of possibly productive coal-measures in the Nizam's territories about Khairgura and Tandúr, and again on the Godávari at Sandrapáli. In the former position actual coal crops were found; at the latter the discovery was quite unexpected, as the ground is greatly concealed, but the indications are considered sufficient. Directions are given for the practical exploration of the measures.

Two localities within this area have long been familiar to students of Indian Geology from the fossils they have yielded—the liassic fish remains of Kota and the triassic reptilian bones of Maléri—and on this account special interest attaches

to Mr. Hughes' stratigraphical determinations. The result, whether local or general, has not been confirmatory of the speculations that had been hazarded upon previous knowledge. Partly from the fossils and partly from the mineral aspect of the rocks, it had been thought that the Maléri beds might represent the Panchet group in the lower Gondwána series of Bengal. From the evidence of some plant fossils obtained during the recent survey, it is, however, decided that these deposits must rank as upper Gondwána. As regards the different horizons suggested, according to the European standards, by the fossils from the two localities, Mr. Hughes' description shews that the beds of Maléri and of Kota cannot be distinguished as separable groups, and therefore that the aforesaid fossils must be taken as contemporaneous in India. This fact, and the affiliations suggested by the fossil flora, present altogether a serious puzzle to palæontologists of the rigid school. The question is briefly stated by Mr. Blanford in a note appended to the description of the Kota-Maléri fossils in a recent number of the Palæontologia Indica. A map and description of Mr. Hughes' work is published in the current number of the Records.

The Kota-Maléri area is part of the continuous spread of Gondwána deposits within the drainage-basin of the Godávari, and hence often spoken of collectively as the Godávari basin or region; but it is only on the lower half of this river itself that these formations occur; the extension above Sironcha is in the valleys of the great tributaries, the Pránhita and Wardha, to where the strata pass under the Deccan trap in the Chánda and Wún districts. The portion below Sironcha is considerably larger than that above it, and Mr. King has been for several seasons engaged in studying this ground. Notices of his discovery of marine beds intercalated with the upper Gondwánas on the seaward margin of the area, were published at the time; and also his description of some small coal basins within or adjoining the main area. A notice of his preliminary observations regarding the whole area was published in the last May number of the Records. During the past season Mr. King made further progress in unravelling the intricate relations of these closely connected rock-groups, and is still engaged in carrying on these researches: but it is scarcely to be expected that he can complete so difficult and extensive an investigation within the present field-season.

Mr. Foote has been engaged for several seasons past upon the coastal zone of Gondwána deposits, in continuation of his previous published work on these beds in the area around Madras. During the past season he completed his survey of this ground through the Nellore and Gantúr districts up to the Krishna river, thus bringing his lines into connexion with Mr. King's work in the Godávari district south of Ellore. The deposits which were the special object of his study are very obscurely exposed as irregular patches along the margin of the crystalline rocks forming the low ground from the base of the Eastern Ghâts; and on the east they pass rapidly under the alluvium of the flat seaboard. Mr Foote has made considerable collections of the mixed marine and terrestrial fossils peculiar to the Gondwána strata in this position. A description of his work is in course of preparation.

Explorations for coal.—In connexion with the Gondwána formation, record should be made of the coal explorations that have been going on for several seasons past in the Sátpura basin. They were undertaken by Government at my recommendation, and have been carried out more or less to the extent contemplated, but have proved unsuccessful. The observations and chances upon which these experiments were based have been from time to time explained in the Records, so that a brief recapitulation of the circumstances will now suffice. The only outcrop of the coal-measures on the north side of the Sátpura basin of Gondwána rocks is on the Sitariva at Mohpáni. It is there that the structural characters of the outcrop, so close to this obscure main boundary of the basin, should have been practically tested and the continuity of the measures proven. The mining operations there have, however, been hitherto on a very paltry scale, and the work of exploration most inefficiently carried out. The difficulties of the ground are, no doubt, considerable, but not a single trial to the dip of the basin has been carried to the depth at which it could have been expected to touch the coal in the position attempted. The whole ground on the Sitariva is in private hands, and Government could not interfere to insist upon a more effective method of search, so it was reasonably resolved to attempt the exploration of the basin at other less favourable points, where the measures themselves had to be sought for.

In pursuance of this project three classes of trial were indicated. It was shewn that the total cutting off of the Gondwána rocks to the north, along a supposed great fault, was at least not proven; and that therefore it was possible that the coal-measures might in certain positions occur beneath the alluvial area of the Narbada valley. To test this conjecture two borings were made, one at Gádarwára close to the main line of railway, and one at Sukakheri by the side of the branch line, half way to Mohpáni. The former was stopped at a depth of 251 feet, as the tubes could not be forced further, and smaller tubes, to pass down inside the first set, were not then available. The Sukakheri boring was sunk to the depth of 491 feet still in alluvial deposits, chiefly clay; and it is highly creditable to Mr. Stewart, the brace-head man in charge of the work, that with such labour and appliances as he could command he was able to sink so deep. This is a far greater thickness than was at all anticipated for the valley deposits; and the trial has practically answered the question proposed, for it would certainly not pay at present to seek the coal through such a thickness of soft rocks. It is plain, however, that the question whether or not the coal-measures extend in this direction (upon the possibility of which the experiments were undertaken), is not affected by the result.

A second class of trial was based upon the fully proven fact that the thickness and distribution of the upper Gondwána groups are exceedingly irregular. It was thus hoped that the coal-measures might possibly lie at a practicable depth within the basin, in the open valleys of the Dudhi and the Táwa, where the measures, if found, would be free from the many accidents that render the working of them so difficult in the disturbed ground near the boundary. Borings were accordingly put down at Mánegáon and at Kháppa in the Dudhi valley The former was closed at 420 feet, as the depth attained required constant super-

vision upon one work. At the close of last working season the Kháppa boring had reached the depth of 720 feet, altogether by hand—another very creditable performance of Mr. Stewart's. Here again the practical question was solved for the present by the mere fact of depth. No change of formation occurred throughout the boring, so the geological information gained is also limited to the bare fact of thickness. As the progress of boring by hand at this depth is so slow and costly, I could not, under the circumstances, recommend the prosecution of the work. Corresponding trials to these were made in the open valley of the Táwa, along the Betúl and Hoshangabad road, at Kesla to a depth of 302 feet, and at the Suktáwa to 241 feet, with the same result.

A third class of experiment lay in the attempt to find the coal-measures in positions corresponding to Mohpáni, close to the edge of the basin. The inducement here is that Talchír beds, which are the most frequent companions of the coal-measures, occur at several places along the margin of the field. The special objections to this position are the frequent presence of trappean intrusions and the great disturbance of the strata. Three borings were put down at Tundni, ten miles west of Mohpáni. Two of them, at depths of 328 and 172, struck trappean and contact-rocks, being evidently on a belt of intrusive action. The third, more to the south, found no change to 243 feet, where the tools stuck fast; but as the dips were high there was no inducement to renew the attempt.

At the western extremity of the field, on the Moran near Lokartalai, some highly carbonaceous outcrops have long since attracted the attention of explorers. A boring put down to the dip of those outcrops, to a depth of 254 feet, has shewn that these coaly bands do not improve underground; and a later discovery of fossil plants in these beds has shewn that they do not belong to the lower Gondwánas. Two other borings were put down at the lowest point of the section, to try the underlying strata; but at depths of 84 and 88 feet (the holes are 60 yards apart across the strike) an intensely indurated sandstone was struck, in which little or no progress could be made. It is almost certainly the contact bed of an intrusive sheet of basalt, the presence of which would indefinitely reduce the prospect of success; so the project was abandoned. This position also is close to the north boundary of the basin and within the zone of special disturbance.

Two other trials of this series remain to be noticed, those close to the patches of Talchír rocks. One on the road from Piparia station to Pachmarhi, within 50 yards of the Talchír outcrop, was sunk to a depth of 285 feet entirely in coarse mottled deposits of the upper Gondwánas, shewing that their junction with the Talchírs must be exceedingly steep, if not faulted, and that the coal-measures, if present, are beyond easy reach. Another trial, now in progress, on the Anjan, close to the road from Bankeri station to Pachmarhi, is also close to an outcrop of Talchírs; it has reached a depth of 186 feet, entirely in mottled sandy clay of the Bágra group.

These trials may be taken as closing for the present the exploration of this region of the basin, unless in immediate continuity of the Mohpáni field on the Sitariva. Should this fail, the nearest prospect is in the Sháhpur field on the south side of the basin.

Punjab.—Mr. Wynne was fully occupied during last season in mapping the structural features of the tertiary basin between the Salt Range and the mountains to the north, and often spoken of as the Potwár, or the Ráwalpindi plateau. It is, on the whole, a broad synclinal, with many subordinate axes of flexure. The changes in composition of these tertiary deposits according to position with reference to the mountain region and to the great river courses, combined with the great disturbance they have undergone, is a constant obstacle to the attempt to trace the zones of contemporaneous strata. To do this with any certainty will be a work of great labour which the Survey is not at present prepared to undertake; yet until this is done, it will be impossible with any nicety to indicate the order of succession of the vertebrate fauna, which forms the chief interest of these formations. The more regular sections of the corresponding deposits in Sind may furnish this important clue to the horizons in the Sub-Himalayan region. A sketch of Mr. Wynne's work, with an outline-map, is given in the Records for last August.

Mr. Theobald has added largely to our collections of fossils from these rocks in the Potwár during the past season; but it is only in an approximate and often doubtful way that the specimens can be assigned to the different horizons: Mr. Theobald reports favourably of the assistance he has received in this work from the apprentice Kishen Singh. A notice of these collections up to date is given by Mr. Lydekker in the current number of the Records.

The post-tertiary deposits of this region offer a study of much interest. They are found resting upon tilted Siwalik strata at very high levels over the actual river courses, so that prodigious denudation must have taken place since they were laid down. There is much evidence to suggest that glacial action took a direct part in the accumulation of some of these deposits.

Sind.—During the working season of 1876-77, Mr. Blanford and Mr. Fedden completed the mapping of Sind, west of the Indus. A considerable portion of the country had been examined in the two preceding seasons, but in several districts the examination had only been partial and preliminary. In the course of the past season Mr. Blanford re-examined the Khirthar range from its northern termination west of Jacobabad to the neighbourhood of Sehwan; he then re-mapped the cretaceous rocks in the Laki range south of Sehwán, and after completing the geological lines in the Habb valley, and marching westward along the coast as far as Sonmiani, returned to Calcutta at the commencement of March, to continue his work on the geological manual.

Mr. Fedden, starting from Karáchi, mapped the large tract of country west of the Laki range, from the neighbourhood of Sehwan to the sea, an area of nearly 5,000 square miles. The ground had been partially examined before, but the greater portion of the details were completed during the past season. Large additions were also made to the fossil collections previously obtained.

So much of the geology of Sind had been determined in the two previous seasons that no very important additions could be expected. Still several slight, but useful, improvements were effected. The exact relations of the bed of trap

found in the Laki range had remained somewhat doubtful, the country in which the rock occurs being difficult of access, the geology complicated by faults and disturbance, and the topographical map very imperfect. It has, however, now been clearly ascertained that a band of contemporaneous volcanic rock, from 40 to 90 feet thick, intervenes between the base of the Ranikot group (lower eocene) and the cretaceous beds, and there can be no reasonable doubt that this thin lava-flow represents the great mass of the Deccan traps. The geological position of these traps below the eocene group, as inferred from their relations in the lower Narbada (Nerbudda) valley, has thus been confirmed from independent evidence.

The cretaceous beds between Ranikot and Laki have been found to be above 1,000 feet thick, their base not being exposed, and they are sub-divided into three groups marked by differences of mineral character and of fossils. The lowest group is the limestone in which a *Hippurite* was found last year.

In the Laki range and the country around Jhirk and Tatta, the nummulitic Khirthar limestone rests upon the Ranikot group, the latter being about 2,000 feet thick where most fully developed, and overlying the traps and cretaceous beds above noticed. But west of the Khirthar range, in Upper Sind, Mr. Blanford found, in a traverse which he made for a short distance beyond the frontier on the upper Gáj river, a thickness of at least 10,000 feet of beds underlying the Khirthar limestone, and having no resemblance to the rocks in the same position to the south-east. These lower beds on the west of the Khirthar range consist of shales, limestones, and sandstones; and fossils were detected in places throughout the upper 4,000 or 5,000 feet, the lower portion being apparently unfossiliferous. All the fossils found were nummulitic and shewed the rocks to be of eocene age. Somewhat similar beds were observed on the Habb river, where the great mass of Khirthar limestone, so conspicuous throughout the greater part of Sind, completely thins out and disappears in the course of 20 or 30 miles. The calcareous shales and sandy beds which replace the limestone, and the very similar rocks seen beneath the typical Khirthars on the upper Gáj, are identified by Mr. Blanford with the beds which he traversed in Western Makrán, between Gwádar and Jálk, in 1872.

Both Mr. Fedden and Mr. Blanford have found that all the tertiary groups of Sind, although well marked and distinct in places, pass into each other elsewhere, thus repeating, in the extreme west of India, the phenomena already noticed in the Himalayas. It has been found very difficult in many cases to map the distinctions between the different groups. In parts of Lower Sind near Karáchi the Gáj (miocene) and Manchhar groups appear to be completely intermingled, typical representatives of both being interstratified. This shews that the connexion between these two groups is closer than was at first supposed, and further evidence tending to a similar conclusion, and adding greatly to our previous knowledge of the later tertiary *Vertebrata*, has also been derived from the collections of mammalian remains made in the Manchhar beds.

A few mammalian teeth and bones were found by Mr. Fedden in 1875-76 in the beds of the Manchhar group, and, on examination by Mr. Lydekker, were found to comprise some forms found also in the Siwaliks, together with others unknown elsewhere, but having a somewhat older facies. In the course of the

past season a considerable addition has been made to the fossils previously obtained, and amongst other forms teeth of *Sanitherium*, *Anthracotherium*, *Hyopotamus*, *Acerotherium*, and *Amphicyon* have been procured; all have been determined by Mr. Lydekker. Several of these were found by the native assistant, Hira Lal, who accompanied Mr. Blanford; others were obtained from native collectors. The specimens are rare and fragmentary, but sufficient has now been learned of the fauna to shew that it is older than the typical fauna of the Siwaliks, and that it should be classed probably as Miocene.

It has already been mentioned in a previous report that the typical Siwalik fauna has been principally derived from beds in the middle of the group. All the fossils hitherto procured from the Manchhar strata of Sind are from close to the base, from the very beds which pass into the Gáj group, already shewn to be probably of miocene age on independent grounds. We have now found evidence of three later tertiary mammalian faunas in India; (1) that of the lower Manchhar group and of some allied forms elsewhere; (2) the typical Siwalik; and (3) the pleistocene Narbada fauna, other intermediate formations having also been indicated. The Manchhar group has proved to comprise a great thickness of beds, probably not less in places than 8,000 to 10,000 feet; only a few fragments of bones have been found in the higher portions of the group, which may very probably represent the fossiliferous Siwalik rocks.

The march to Sonmiani was undertaken in the hope of tracing a connexion between the Manchhar beds and the highly fossiliferous rocks of late tertiary age on the coast of Makrán, but unfortunately the break between the beds of Sind and those of Makrán appears to be greater than was supposed, the only formations seen between Cape Monze and Sonmiani consisting either of rocks certainly not of later date than eocene, or else of subrecent and alluvial deposits, whilst no appearance of the Makrán beds could be detected except at a considerable distance west of Sonmiani.

Mr. Fedden has done a very good season's work, and has made a large and valuable collection of organic remains in the present and preceding years. He has now been sent to Kattywar to commence the survey of that province, his knowledge gained of the rocks in Cutch and Sind being a great advantage in studying the formations of the neighbouring peninsula of Guzerat. Since his return from privilege leave Mr. Fedden has been most usefully engaged at head-quarters in making a preliminary arrangement of the extensive series of fossils from Sind.

One of the native assistants attached to the Survey in 1874 was sent with Mr. Blanford and another with Mr. Fedden, principally as fossil collectors. The former, Hira Lal, although requiring much additional training, proved useful and shewed great willingness; but the assistant who accompanied Mr. Fedden, Ram Sing, was found to be of very little service, and as there appeard no prospect of his ever giving any assistance of value, it was recommended that his probationary service should terminate. He has since, by order of Government, been removed from the Survey.

Mr. Blanford, since his return from the field in March, has been engaged in office work, and especially on the preparation of the geological manual.

During the past field-season none of the officers of the Survey were absent on sick leave or furlough; and still, compared with some seasons gone by, our muster-roll was short, sanction not being yet obtainable to fill the last three vacancies. In view of the work remaining to be accomplished, especially in the geology of the Himalayas, for which arduous work a man must be in full physical vigour, this temporary suspension of our powers is much to be deplored.

Publications.—It is pretty generally understood that in mixed publications of acknowledged authorship the writers are separately responsible for the opinions expressed, the editor's veto being reserved for open breaches of logic or of propriety. As, however, I have been supposed to hold certain views, because they were allowed to appear in the Records of the Survey, it would seem to be the opinion of some that an official body of workers should run in a groove, that the chief of the staff should consider himself so superior to his official subordinates as to form, or at least control, their opinion. The notion may be a relic of the early British idea that a geological survey might be mainly carried on by men devoid of mental culture or scientific training, the materials so collected being worked into shape by a responsible head. In a civilised country, where the main lines of the work are already laid down, and where it is always easy to visit and study any crucial features of the ground, such a system might, to some extent, be practicable; but the attempt would be impossible in India, where, off the main highways, one can only move about with all the incumbrances of a camp; so that the work of inspection would take nearly as much time as the preliminary survey. But, indeed, there is no cause to regret the absence of a system based upon an essentially narrow idea of geological work, in which the important duty of making and recording observations of obscure facts is entrusted to men who can have but a feeble conception of what they are about, and who are without the sure incentive of responsibility for the finished work.

No doubt, however, a chief of the staff is in a peculiar position as editor of a departmental publication, but it seems to me that the rationale of the position tends in our case to loosen rather than to tighten the bonds of his responsibility. As official head of a body of scientific workers, his functions are rather those of the heads of the intelligence and commissariat departments than of the commanding officer. Unless under very unfortunate circumstances, he would certainly have colleagues as competent as himself to do work, and to whom any dictation on his part would be impertinence. In so complex a business as a geological survey, there must be several experts more proficient in their several branches than any one can be in them all, and whose work can only be fully criticised by their peers. Thus, then, the business of the department being to collect and publish information, which is not obtained by manual operations performed by rule, but must be the result of pure intelligence, every member has more or less of a right, according to his ability to produce finished work, to appear as author of that work. And so, under anything like normal conditions, the editorial responsibilities become distributed; and so far, too, it becomes unreasonable to charge the Survey collectively, or its official head, with views that may be taken by one of its members. In many matters, uniformity

must, of course, be insisted on; but some freedom of speculation is necessary to the individual life.

Several considerations of expediency support these principles of right. It would be absurd to accept and publish a man's description of objects or phenomena and not allow him to expose his reasoning thereon. The elements of observation in geological researches are not simple, or to any extent quantitative; they can only be fairly exhibited when put together in argument; and this test is also needed to discover the bias of the observer's mind, the colour of his spectacles, and hence the value even of his plain record of facts. No less may this public exposure be needful to bring the observer to his senses. Ignorance or conceit that would be quite unmoved by individual opinion, may stand corrected before a competent public opinion; and the want of a critical public in India is perhaps the most serious obstacle to our progress. In the absence of local censors we must seek for them abroad, or even permit some mutual criticism in our own ranks. Unfortunately error itself, as presented by a man of any professional education, is often under the protection of the majority; but in this case, too, exposure is the only remedy. On the other hand, coercion and suppression are fatal to human energy of any kind, especially to the development of thought; and mutual encouragement to thought should be the ruling relation in a body of colleagues united in the bonds of a common study.

These considerations are not intended to cover any shirking of the great responsibility that undoubtedly attaches to my post, but only to meet certain false views of what these duties are. There are very special dangers and difficulties in the course I would take; notably the encouragement offered to impostors by facility of publication. Men who have nothing to say worth listening to are often the most anxious to come forward; they would fain measure their own worth by the number of papers or the amount of print having their name attached,—floods of inane descriptive matter without a suggestion of meaning (as if any man could extract positive knowledge from the observations of quacks), or else one-sided pictures from the point of view of some foregone conclusion. We must only recollect that there can be no wheat without chaff and straw, and that the human mind is not an annual that flowers only once, but a strong plant that can bear much pruning and grafting.

The foregoing remarks will explain how the RECORDS of the Survey for the past year have swelled to unusual proportions, but I trust that, on the whole, the change has been to the advantage of our public and ourselves.

I have to apologise for the non-fulfilment of a promise made in the last annual report. Inexperience of large undertakings and a too sanguine temperament led me to hope that the Map and Manual of the Geology of India could be ready by the middle of the past year, whereas much still remains to be done on both, although, with due regard to other necessary work, no time has been lost in their preparation. We can, I think, with certainty promise it for the middle of the current year.

Volume XIII of the MEMOIRS was issued early in the present year, with coloured maps of two important areas—the Rajmahal hills and the Wardha valley coal-fields.

Volume XIV, containing Mr. Wynne's description of the Salt Range, with numerous plates and illustrations, was fully printed off before the end of the year, but there will be unavoidable delay in its issue on account of the map, which presents an intricate piece of colour-printing, and the lithographic branch of the Surveyor General's Office has been so much engaged upon the geological map of India that the printing of the Salt Range map has been inevitably postponed.

I am glad to announce that all the fossil collections from the Salt Range, below the nummulitic horizon, have been confided for description to Dr. Waagen, who studied the formations on the ground and added largely to the collections. As the Survey has been so unfortunate as to lose Dr. Waagen's permanent services, through his inability to endure the Indian climate, we are most fortunate to have secured his co-operation in this very important work, for which he is so eminently qualified.

Of the PALÆONTOLOGIA INDICA three fasciculi were issued before the close of 1877: two (Ser. II, 2 and 3) by Dr. Feistmantel on the flora of the Rajmahal group in the Rajmahal Hills, and near Golapili, in continuation of the work by Dr. Oldham and Professor Morris on the same group of fossils, published in 1862. The third is by Mr. Lydekker, forming the second number of Series X, devoted to the description of the Tertiary Mammalia.

Through the kind services of Dr. Oldham in England, we have obtained descriptions by Sir Philip Egerton and Professor Miall of some interesting vertebrate fossils from the Gondwána deposits of Kota-Maléri. The printed sheets and plates of this work were received in Calcutta before the close of the year and have since been issued, with a supplementary note by Mr. Blanford on the stratigraphy and homotaxis of these deposits.

Two other fasciculi of the Palæontologia were finally passed for press before the close of the year and are now ready for issue: one (Ser. XI, 2) by Dr. Feistmantel on the Flora of the Jabalpur group; and one (Ser. X, 3) by Mr. Lydekker on some Siwalik Mammalia.

Library.—During the year 1877 the library of the Geological Survey has received an addition of 1,355 volumes; 784 by purchase and 571 by presentation or in exchange.

For the last three months the library-room has been in great disorder during the construction of a gallery and additional cases. As soon as this work is completed and the books arranged, the whole will be carefully checked and compared with the manuscript catalogue, which will then be printed.

Museum.—Much progress has been made in bringing the Museum into order. In December the new wall-cases in the main palæontological gallery were finished; and they are now completely filled with our standard series of fossils in biological succession, though of course at present only in rough generic order. The final arrangement and labelling of the specimens on the shelves will be a tedious labour. In the gallery for Tertiary Mammalia the wall-cases were also finished in December. Mr. Lydekker has these collections so well in hand that the whole are now in excellent approximate order with suitable labels.

In the mineralogical gallery a new set of table-cases were provided during the past year for the minerals and rocks; and, thanks to Mr. Mallet's industry, our valuable series of mineral types is now laid out in perfect order. A valuable addition to this collection was made during the year by exchange with the Mineral Department of the British Museum.

Mr. Mallet has also made much progress with the classification of our collections of economic minerals, both Indian and foreign. This is a branch of our work to which I hope to direct more attention than it has hitherto been possible to do for want of space.

Series of rock specimens, both Indian and foreign, have also been laid out. In the Indian series we must for long be content with much apparent disorder, or at least temporary grouping and labelling, for it represents the current state and progress of the geology of India, which is far from having approached completion. The collection is not even up to date, for hitherto it has been necessary to discourage the collection of rock and mineral specimens for want of place to keep them in.

The geological galleries of the Museum have been open to the public since the 1st January of this year.

H. B. MEDLICOTT,
Supdt. of Geological Survey of India.

CALCUTTA,
January 1878.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1877.

AMSTERDAM.—Royal Society of Batavia.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Sciences.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
BOSTON.—American Academy of Arts and Sciences.
,, Boston Society of Natural History.
,, Museum of Comparative Zoology.
BRESLAU.—Silesian Society of Natural History.
BUDAPEST.—Royal Geological Institute of Hungary.
BUFFALO.—Buffalo Society of Natural Sciences.
CALCUTTA.—Asiatic Society of Bengal.
,, Meteorological Survey.
COPENHAGEN.—Royal Danish Academy.
DAVENPORT.—Academy of Natural Sciences.
DRESDEN.—The Isis Society.
DUBLIN.—Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society.
GENEVA.—Physical and Natural History Society.

GLASGOW.—Geological Society of Glasgow.
,, Glasgow University.
,, Natural History Society.
,, Philosophical Society of Glasgow.
LAUSANNE.—Vandois Society of Natural Science.
LIVERPOOL.—Geological Society of Liverpool.
,, Literary and Philosophical Society.
LONDON.—British Museum.
,, Geological Society of London.
,, Linnean Society.
,, Royal Asiatic Society of Great Britain and Ireland.
,, Royal Geographical Society.
,, Royal Institution of Great Britain.
,, Royal Society of London.
,, Zoological Society of London.
MADRID.—Geographical Society of Madrid.
MANCHESTER.—Geological Society.
,, Library and Philosophical Society.
MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MOSCOU.—Imperial Society of Naturalists.
MUNICH.—Royal Astronomical Office.
MUNICH.—Royal Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Science.
NEW HAVEN.—Connecticut Academy.
,, Editors of the American Journal of Science.
PARIS.—Geological Society of France.
,, Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PLYMOUTH.—Devonshire Association.
,, Royal Geological Society of Cornwall.
ROME.—Geological Commission of Italy.
,, Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SALEM. MASS., U. S. A.—American Association for the Advancement of Science.
,, Essex Institute.
ST. PETERSBURG.—Imperial Academy of Sciences.
SYDNEY.—Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Science.
VIENNA.—Imperial Academy of Sciences.
,, Imperial Geological Institute.
WASHINGTON.—Department of Agriculture, U. S. A.
,, Smithsonian Institute.

WASHINGTON.—United States Coast Survey.
" United States Geological Exploration of the Fortieth Parallel.
" United States Geological Survey of the Territories.
WELLINGTON.—Geological Survey of New Zealand.
" New Zealand Institute.
YOKOHAMA.—German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.

Governments of India, Madras, Bombay, and the Punjab; Chief Commissioners of British Burma, Central Provinces, Assam, and Mysore; Superintendent of the Revenue Surveys; and the Resident, Hyderabad.

Notes on the geology of the upper Godávari basin, between the River Wardha and the Godávari, near the Civil Station of Sironcha, by THEODORE W H. HUGHES, A.R.S.M., F.G.S., *Geological Survey of India.*

In the Memoir on the Wardha valley coal-field, an arbitrary line along 19° 30′ north latitude was adopted as the southern limit of the field, there being in that direction no definite geological boundary of contrasting rocks within the geographical confines of the Wardha valley. The same series and groups, in fact, stretch continuously to the south-east beyond the Wardha field, down the adjoining valley of the Pránhita and that of the Godávari, for more than 230 miles, thus making one great geological region, embracing a large portion of the drainage area of three distinct and important rivers. This region, which, towards the north, has mainly been surveyed by Mr. Fedden and myself, has, towards the south, been under Mr. King's care. We have now brought our leading geological lines from each side to the Godávari river, and there only remains the work of investigating the slight difference that must necessarily have arisen when observers start from widely separated points. This duty Mr. King undertakes next season.

My most recent field notes refer to the district between the Wardha valley and the Godávari (from Naspúr to Sironcha), an area that has up to this time been only cursorily examined.

I was able to distinguish in descending order the—

Trap series—

Chikiala	**group**	"Gondwána" system.
Kota-Maleri	"	
Kámthi	"	
Barákar	"	
Tálchir	"	

Vindhyan series.
Metamorphic series.

A.—METAMORPHIC AND VINDHYAN SERIES.

The rocks of the metamorphic series were found always exterior to the Gondwána area. With one exception this is also the case with the Vindhyans:

from Metindáni, in the north-west, to Berda they are the fringing rocks; again, from Kairgúra to Naspúr, and from Mútlágúram, on the Pránhita, to the neighbourhood of Bijôr. Near Chinúr, however, there is an inlier of Vindhyans of several square miles in extent.

On the east and the north sides of this inlier, the Gondwánas appear to rest naturally on the Vindhyans; but on the west face the former are, I think, faulted against the latter, as no group of older age than the Kota-Maleri is seen in that direction, whereas, on the Chinúr side of the inlier, Tálchirs occur, and at the same surface level. The alternative supposition that the contact of the Kota-Maleris and the Vindhyans is an original one—all the older groups of the Gondwánas having thinned out—is highly improbable in face of this fact of similarity of surface level; and there seems to me to be further proof of the fault in the Godávari itself, where the Kota-Maleris are in contact with the boulder bed of the Tálchir group,—high and reverse dips being visible.

It was impossible to trace the fault in a north-west direction beyond the vicinity of the inlier, but on the map I have indicated a probable course.

B.—GONDWANA SYSTEM.

I.—*Tálchir Group.*

This, the lowest group of the Gondwána system, occupies a long belt of ground along the western border of the Gondwána area; a small strip near Chinúr; and a few little patches elsewhere.

Needle shales not prominent.

Its characteristic features are well seen in many sections, but the needle shales, instead of being the most prominent rocks, are quite subordinate to the sandstones. It was rare indeed to meet with any of the former. The boulder bed, however, is strongly developed, and in some places is the only representative of the group. This is so in the case of the little patch of Tálchirs near the boundary of the Vindhyans north of Naogaon. The boulder bed is conspicuously exposed in the vicinity of Mádorám, and near Tándúr; and more or less continuously from Kásipúr to Naspúr. In the Godávari river, it is seen on the right bank near Sandrápali. Many of the boulders are of gneiss and of enormous size, but the generality are small, and consist mainly of Vindhyan shales, limestones, and sandstones.

Gneiss boulders indicative of Tálchir formation.

It is easy to trace the extension of the Tálchirs northwards in the direction of Chinúr by means of the boulders strewn on the surface; many of the blocks being of gneissose and granitic composition. Such, when met with, may, I think, unhesitatingly be accepted as signs of the Tálchir group, not a single instance of their occurrence in any of the other groups of the Gondwána system having ever come within the range of my experience. The doubts that assailed me as to the true horizon of the boulder bed when I first noticed it near Sandrápali were dispelled so soon as I discovered gneiss and granite boulders.

The boundaries of the Tálchir group are almost everywhere those of original contact; but in the neighbourhood of Kásipúr, and between that village and Aknápali, there are several faults. The most distinct of them is the one that I

have indicated as being probably the continuation of the fault along the west face of the Vindhyan inlier near Chinúr. It is very plainly seen a few yards below the junction of a small stream with the river shown on the map as flowing from the direction of Batwanpali towards Kásipúr. The dip of the Tálchirs is in contrast with that of the Vindhyans, the latter varying between 20° to 40° east of north, that of the former being north-westerly.

I have not been able to trace, as closely as I could have desired, the limits of the Tálchirs between Sárangpali and Naspúr. Amongst the causes that prevented me from so doing, the most trying difficulty to encounter was the real or pretended incompetency of the guides. They could direct me from their own village to the next one so long as I kept on the main road, but if I ventured to strike into the jungle, troubles at once commenced, a cloud of incomprehension settled on them, and to every question regarding distances, relative positions of rivers, hills and villages, I received one constant answer "*Yerki ledu,*" "don't know." It may be that the tendency of the people (Gonds and Kolams) to change their place of habitation at short intervals, prevents them from becoming acquainted with more than a circumscribed area around their temporary houses, but on many occasions I suspected that ignorance was affected in order to avoid possible compulsory service of unknown duration.

In addition to the infliction of unqualified or unwilling guides, supplies were difficult to procure, villages being small and far apart, and a more than usually large number being deserted[1] owing to the want of water, there having been a failure of rain in the monsoon.

Map unreliable near Sárángpali.

The map was a most unreliable source of reference in many instances. For example, near Sárángpali, the large river west of the village is shown as being distant about a mile, whereas in reality it is nearly three miles away. And the river east of Sárángpali, instead of rising in the neighbourhood of Yenkatápúram, takes its origin near Sárángpali. The error in placing the large river west of Sárángpali so close to the village, has thrown my boundary line entirely out, and I have had to reduce the real breadth of the Tálchir exposure by at least three-quarters of a mile.

I failed to discover any organic remains, although I occasionally made very diligent search in places where I hoped success might reward my labours. That the Tálchirs contain several plant forms has been demonstrated by Dr. Feistmantel, and I was extremely anxious to collect a few specimens from the upper Godávari area, in order to compare them with the flora of our Bengal fields.

II.—Barákar Group.

The lithological features of this group are quite as characteristic here as in the Wardha valley, and there is no difficulty in recognising the formation where there is a fair exposure of it. But the drawback to identifying it, and tracing its boundaries, is the fact of the very incomplete sections that one has the opportunity of examining. It will be seen by looking at the map that no Barákars are shown

[1] It is the wont of the Gonds and Kóláms to leave their homes in the warm season for service with the proprietors of villages whose lands are more fertile and better cultivated than their own.

overlying the Tálchirs between Kásipúr and Tétmatla on the left bank of the Godávari. Now, I am by no means prepared to assert that Barákars do not occur exposed at the surface, but in the absence of a single section to which I can refer as yielding undoubted evidence of the presence of Barákar strata, I have preferred to suppress the probable boundary lines which it would have been easy for me to indicate. The more so also, as perhaps an erroneous impression might have been conveyed respecting the possible existence of coal.

Actual coal outcrops occur only in a few places. There are none in the small patch of Barákars overlying the Tálchirs north of Naogaon. But in the belt of rocks extending from Kairgúra to Tándúr and onward, there are several exposures of coal.

Coal seam near Kairgúra.

The most northerly of these is one near Kairgúra. The seam is seen in the right bank of the river that flows past the village in the direction of Chirákúnt, a few yards north of the Tiráni road ghât. Only a portion of its total thickness is visible. Descending, the section is:—

Coal	3′·0″
Carbonaceous shale	0′·8″
Coal	0′·7″
Carbonaceous shale and coal	...

The dip is a little east of north, at an angle of 15°.

In a small stream, east of the main river and tributary to it, a much clearer section of the seam is exposed, and its entire thickness is 15 feet. Most of it is coal, and much of it of fair quality. The average composition is, according to an assay made by Mr. T. H. Turner, the Assistant Curator of our Museum,—

Volatile matter (moisture 9·4 per cent.)	42·2
Fixed carbon	45·6
Ash	12·2
	100·0

Like the coal of the Wardha valley, and those of the several Godávari fields, there is a large amount of moisture in this sample. The fixed carbon is somewhat deficient, but the proportion of ash compares favorably with the standard for ordinary Barákar coals. Underlying the seam is sandstone identical with that which in the Wardha valley I have described as "nodular sandstone," and which there always occupies a position immediately or almost immediately (argillaceous shale sometimes intervening) under the coal. In the area that I am now describing, this kind of sandstone is constant in such sections as are exposed, and I would accept it as an almost sure sign of coal.

There are no Tálchirs seen below the Barákars, in the river or elsewhere near Kairgúra, the former being overlapped by the latter, which here rest naturally upon the Vindhyans.

Coal outcrop between Kairgúra and Ábápúr.

The next outcrop of coal that I met with was about half-way between Kairgúra and Ábápúr. I look upon it as being the extension of the Kairgúra seam in a south-easterly direction. At the surface it shewed a diminished section, being only 5 feet,

instead of 15 feet thick. It is probable, however, that when sunk into, an increase will be proved. The quality of the coal appears to be the same as that at Kairgúra, and it possesses the same tendency to split, after exposure to the air for a short time.

Outcrop near Gúloti.

Another outcrop of this seam may be seen in the branch stream of the Gúloti river coming from Ábápúr. It is, as usual, near the top of the group, and is underlaid by very typical nodular sandstone. There is no other section in which the Barákars are so fairly exposed as in this one; and all the rocks are sufficiently characteristic to render their determination a matter of ease. The total thickness of the seam measurable is 9 feet. The direction of its dip is north 20° east, and angle of inclination 11°.

Bore-hole positions.

I met with no other outcrops of coal, except the three mentioned above; but the fact that coal occurs, and is visible at intervals over a length of seven miles of country, makes it highly probable that it is continuous throughout the belt of Barákars from Kairgúra to Aknápali. To test this point, bore holes may be put down anywhere near the junction of the Kámthis and Barákars, some allowance being made for overlap, for here, as in the Wardha valley, the former creep over the shore edges of the latter.

Sandstones resembling Barákars.

From Aknápali to Tétmatla, there are no Barákars shown upon the map. As I have already said, I am not prepared to maintain that they are absent, but I did not come across a single section which satisfied me that the rocks I saw were those of the Barákar group. Near Tétmatla there are sandstones which at first sight are somewhat difficult to discriminate from Barákars. In colour and texture and composition they are undistinguishable, but their method of weathering is different. They have rounded outlines, and they have lost the distinctness of their lines of stratification—a feature not usually observable in the Barákars, but common in the Kámthis. I have accordingly placed them in the latter group.

Borings recommended.

Although Barákars are not seen, it is quite possible that coal exists, and I would advise sites near Sárángpali, Yenkatápúram, and Tétmatla as being likely to prove successful in the event of borings for coal being undertaken. In the river east of Tétmatla, about 500 or 600 yards above its junction with the Godávari, there are some very promising Kámthi sandstones, and a hole of 300, or at the most 400 feet, ought to strike coal if it occur.

Probable occurrence of coal at Sandrápali.

The only other remaining Barákars in the field that I could recognise occupy a narrow strip of country extending from Chinúr to Sandrápali. That these rocks are of Barákar age, is testified by their well-marked lithological characters; and in the Godávari the nodular sandstone is a prominent and specific indicator of the group. The thickness of the entire series of beds is under 200 feet. There is no outcrop of coal, but the sandstone immediately under coal occurs at the mouth of the Sandrápali stream, and a boring in the right bank of the Godávari, a little below the union of the two rivers, will in all likelihood strike coal, within a moderate depth from the surface. I found large fragments of coal in the bed of the Godávari

opposite Pálgúla, and I traced them up to within a mile or so of Sandrápali. This discovery was additional, and very satisfactory, evidence of the existence of coal somewhere in the neighbourhood of Sandrápali, and I have no doubt whatever that the site I have recommended for a bore hole is a spot which, when tested, will justify the anticipations that my observations have given rise to.

Two of the pieces of coal that I picked up, I sent to the Tahsíls of Chinúr and Madápúr to be deposited there and shown to such as might be interested in mining matters, and who perchance would pay a visit to Sandrápali on hearing of the likelihood of coal being found in the vicinity.

Measuring as the crow flies, Sandrápali is only six miles from Sironcha, a station that, by the completion of the Godávari navigation scheme, would be brought into communication with the coast line of the Bay of Bengal. In the event of steamers plying up and down the river, it would be a convenient depôt for coal, with the advantage of being in British and not foreign territory.

Expectation of coal at Kota not realised.

Some thirty years ago, hope and rumour pointed to Kota, a fortified village on the left bank of the Pránhita, four miles above Sironcha, as a likely locality for coal. The expectation was never realised, but it is somewhat interesting to know that if efforts had been guided to an almost equal distance from Sironcha, and in a direction opposite to Kota, coal might perhaps have been discovered.

The question of available fuel near Sironcha is not of such moment with reference to the requirements of a railway, supposing the Wardha Valley State line to be pushed on in the direction of Haidarábád. Such extension would probably follow a course that would render the localities at which outcrops have been mentioned, or the spots where borings have been recommended, more convenient centres of supply.

Borings at Sandrápali advised.

That coal occurs at Sandrápali is, of course, only a supposition, but a supposition that, according to my belief, is very little removed from a certainty, and as a shallow boring or two will suffice to set doubts at rest, I would advise early action in the matter to be taken. With positive knowledge of the existence of coal, instead of a hypothetical basis to go upon, schemes depending upon the accessibility of coal within given limits may probaby be brought to an issue.

To my knowledge there are no Barákars in the valley of the Pránhita, and I was unable to recognise any along the north-east boundary between Mútlágúram and Kirmíri.

III.—Kámthi Group.

Porous sandstones, typical rocks.

In the determination of this group, I have been mainly guided by my experience of it in the Wardha valley coal-field. At the base, we there had a series of sandstones usually coarse-grained, porous and friable, and slightly yellow, reddish-brown or grey in colour; above, more compact sandstones. The character of the sandstones at the base is what I wish to draw attention to, for in several places in the area that I am describing in this paper, I have depended upon the porosity of the sandstones for the correctness of my assignment, but, of course, it must be understood only when the sandstones exhibiting this feature were at such an

horizon that the analogy with the Wardha valley might be quoted to justify my having done so.

As specific rocks in the higher portion of the group, I have accepted the compact argillaceous shales and sandstones of deep red, buff and pale purple colours, they being very characteristic, both in the district from which the Kámthis derived their name, and in the Wardha valley.

The mapping of the Kámthis has been beset by the same difficulties, arising from imperfection of sections, &c., as were experienced in the case of the Tálchirs and Barákars. The aspect of the strata composing the Kámthi group being also much more diversified, it was not always that one could vouch so positively for the correctness of one's determinations of isolated rocks as in instances where Tálchirs and Barákars were concerned. There is not the sameness in the Kámthi group, as in the other two, and it was always necessary that one should be prepared to receive as a portion of its series a bed of uncertain aspect.

Lower boundary of group fairly accurate; upper boundary questionable.

The lower boundary of the Kámthis may be accepted as fairly accurate throughout, but the upper is open to possible correction. Mr. King and myself differ slightly as to what shall be considered the limit to the Kámthi group. In his paper, contributed to the Records of the Survey (Vol. X, page 55, 1877) he introduces between the Kámthis and the Kota-Maleris, a group consisting principally of sandstones, which he names after the town of Sironcha. I see no necessity for establishing this group. The sandstones from Sandrápali to the junction of the Godávari and the Pránhita at any rate are undoubtedly Kámthis; and sandstones differing in no respect from those opposite Sironcha are to be found above what I imagine to be beds of undisputed Kota-Maleri age. One of the chief reasons for the elevation of the Sironcha sandstones into a separate group was founded upon an erroneous observation which modified a case of oblique lamination into one of unconformity.[1] On re-examination, this season, of the section (which Mr. King and I on the first occasion visited together) where we formerly thought ourselves justified in concluding that there was a slight unconformity in the succession of the beds, I saw reason to change my opinion. Referring the point to Mr. King for his judgment, he, after inspecting the section again, agreed with me. As therefore there is no break, I am inclined to throw the boundary of the Kámthis more to the north and east, thus subtracting a considerable thickness of beds from the Sironcha group. It is quite true, as Mr. King remarks, that opposite Sironcha the sandstones differ in many points from those of the country to the south (and north-west). "They are *micaceous*, thick and thin-bedded, harsh, even-textured, grey and brown sandstones, but they at the same time contain fragments of buff and pink shales." On lithological grounds I think they are separable from the Kámthis, and so far I agree with Mr. King, but, instead of isolating them, I would place them with the Kota-Maleris.

The leading characteristics of the Kámthis within the limits of my work, correspond with those already set forth in the first place by Mr. Blanford,

[1] Records, Geological Survey of India, 1877, Vol. X, Part II, page 61.

and in the second place by myself.[1] It seems to me unnecessary therefore to repeat them in a special paragraph, the purpose of this paper being satisfied if I allude to them incidentally while describing the distribution of the group.

The most northerly rocks are those which form the extension southward of the Kámthi area, the description of which in the Memoir of the Wardha valley ended at the arbitrary boundary of 19° 30′ north latitude.

The bottom coarse-grained, porous and friable sandstones are very well exposed in the river flowing past Mérpali in the direction of Sirpúr, and along the west boundary generally they are clearly seen. They rest upon Vindhyans as far south as Chitakúnta.

The upper rocks, consisting of fine-grained, compact sandstones; granular, brown, ferruginous sandstones; and coarse, white and grey, felspathic sandstones, constitute high land north and south of the Mérpali river. They are gradually overlapped by the Kota-Maleris as they extend southward, and where the boundary turns to the west, there is a great decrease in the thickness exposed. A moderately fair section of the Kámthis is seen in the Jangaon river, and near Dabágúr there is a thin bed of slightly carbonaceous shale. It is so very rare to meet with anything at all approaching carbonaceous shale in the Kámthis, that I notice its occurrence in the present instance as being an unusual circumstance. Above Dabágúr, towards Rájúr, there are some red clays associated with the sandstones, and this gives some ground for suggesting that the determination of these as Kámthis is incorrect; and that they ought to be placed amongst the Kota-Maléris. Red clays are certainly very common amongst the Kota-Maleris, and especially so in the Jangaon valley, but the sandstones with which the red clays in question occur, are not of the Kota-Maleri type, but resemble closely some of the sandstones of the lower series of the Kámthis. South of the Jangaon river the Kámthis appear in their greatest force and stretch for 50 continuous miles from Chirákúnt to the banks of the Godávari. All the different varieties of sandstones that the group possesses are represented: the compact grits breaking with a conchoidal fracture, the blotchy sandstones, the ferruginous sandstones, the porous sandstones, &c., &c. The middle and the upper sandstones form a good deal of high land. Towards the base of the principal range of hills extending from Némúr to Kansápet compact argillaceous sandstones occur. These are very characteristic rocks of the Kámthi group, but they are by no means of such frequent occurrence in the Godávari area as they are a hundred miles further to the north.

Looking at the map, it will be seen that in the Godávari river above Sandrápali, I have marked the upper limit of the Kámthi group as being near Arénda. By this assignment, the rocks that Mr. King distinguished as Tárchérla sandstones (from a village 12 miles to south-south-west of Arénda) are brought within the embrace of the Kámthi area. I believe the evidence as to the true position of these Tárchérla sandstones further to the south is somewhat obscure, it being possible indeed to infer that they are lower in the series than the Kámthis. Unless the rendering of the Godávari section, however, has been

[1] Memoirs, Geological Survey of India, Vols. IX and XIII.

complicated by faulting that I have overlooked, the Tárchérla sandstones are, I think, more properly placed with the Kámthis than below them.

Kámthi group near Chinúr.

Rocks that I consider to be Kámthis occur east of Chinúr, and overlie the Barákars at Sandrápali. The porous type sandstones are exceptionally well developed near Chintálapúr, where they form a low ridge striking north-west and south-east. The more compact varieties are best seen in the direction of Kotapali. The upper boundary as marked by me, near Sironcha, is open to question, for the reason already pointed out, that Mr. King is inclined to introduce a group between the Kámthis and the Kota-Maleris. To the introduction of this group I am somewhat opposed, the grounds for the separation being to my mind insufficient.

IV.—Kota-Maleri Group.

Overlying the Kámthi group are the Kota-Maleri beds, made up largely at the base of red and green clays; fine-grained, speckly-grey sandstones; open mottled purple or red and white sandstones; thick-bedded white sandstones, with coarse gravel scattered through it in parts or occurring in ill-defined runs; soft and somewhat unctuous sandstones of various colours; and pisolitic argillaçeous sandstones and grits: most of these lower sandstones contain clay galls. The clays, and more especially the red ones, are the most conspicuous beds of the group, and at the same time form a very striking feature in the surface aspect of the country. Over considerable areas, nothing but red soil is to be seen, and for many miles between Bibra and Nakalápali, on the high road to Sironcha from Chánda, this is the predominant colour.

The clays are by no means constant in thickness, their most profuse development being in the west and the north-west division of the map. In the section exposed by the Pránhita, the proportion they bear to the other rocks of the group is small.

Clays are not so abundant high up in the series as at the lower horizons.

The dip of the Kota-Maleri group is in conformity with that of the underlying series both in the Godávari and Pránhita sections, but the unconformity of overlap becomes evident when the lower boundary is followed for some distance. In the Memoir on the Wardha valley, I pointed out that this was the case, and the testimony is repeated here.

Associated with the clays are the limestones at Kota, from which the fish *Lepidotus* and *Dapedius* were obtained. At Kota the limestones, like the clays, are not of conspicuous thickness; but, like the latter, they become much more prominent members of the series towards the north-west; and near Bimpúr and Itial, 36 miles from Kota, they form a well-marked, though low hill range. That the limestones so abundantly developed in the north, and there attaining a thickness of over 100 feet at the least computation, are the continuation of the few feet seen at Kota, is, I think, a point fairly established by the likeness that the rocks bear to each other, and by the discovery of fish scales at Itial similar to those found at Kota.

I was not able to trace them much beyond the vicinity of Itial, but in the other direction, and the further side of Kota, Mr. King succeeded in picking them up in the Godávari.

With reference to the clays at Maleri, in which were obtained teeth of the fish *Ceratodus*, and remains of the reptiles *Parasuchus* and *Hyperodapedon*, the Itial limestones, and consequently the Kota limestones are higher in the series. To this circumstance I attach no stronger significance than that of local super-position, for clays and sandstones similar to those below the limestones occur above them, and the evidence appears to me insufficient to justify the separation of the red clays and sandstones of Maleri from the red clays and sandstones above the Kota limestones. The circumstance, that hitherto none of the Kota fish have been found at Maleri and none of the Maleri forms at Kota, may be said to be suggestive of separation; and as the relative position, in which the organic remains occur, is in accord with the experience of European research (*Parasuchus*, &c., occurring in older strata than *Lepidotus*, &c.), there is an additional reason for suspecting a break in the deposition of the Kota-Maleri group. Considering, however, how limited have been our efforts in search of organic remains, it is premature to give much force to the negative evidence that lies before us on this point; and I cannot see how European analogy affects in a decisive manner the grouping of beds in India that are identical in composition and appearance, and amongst which no unconformity in its strict meaning occurs. It may be that the component strata of the Kota-Maleri group, being fluviatile formations, there was changing distribution of deposits, giving rise to irregular beds,—as, for instance, the very clays and limestones that we have been alluding to; but this is quite in accord with the known character of deposits formed under the conditions supposed to have then existed in the Kota-Maleri area, and is no proof of unconformity.

In the Maleri clays, the fossil remains most commonly found are those of *Hyperodapedon* and *Parasuchus*. I have succeeded in extending the area of their occurrence over a large portion of the Kota-Maleri country. One of the localities where they are found is Agrézpali, 4 miles south and a little west of Chinúr, in clays which are high in the series, and presumably much higher than the Kota limestone horizon. But on this point I cannot insist, as owing either to the imperfection of the sections in the Godávari and its valley, or to the absence of the limestone band in this direction, I failed to get direct evidence of the position of the clays relative to the limestone.

Though this failure is to be regretted, the probability is suggested that amongst the clays above the Kota limestone similar reptilian remains to those met with in the Maleri clays may be found. Should this likelihood be converted into reality, the objection that may be founded upon the present evidence and European analogy to the incorporation of the clays, &c., above and below the Kota limestones in one group would be removed.

The higher portion of the Kota-Maleri group is not so characterised by clays as the lower. It is chiefly made up of sandstones, the most typical of which are coarse and loosely compacted sandstones of various colours, with broken runs of buff and pink shale fragments through them, rusty-brown and grey sandstones containing pebbles, and yellowish-grey sandstones, varying in texture, with dark stains of peroxide of iron, and sub-angular pieces of yellow opaque quartz scattered through the rock.

Sandstones containing shale fragments are found at various horizons, but they are of most common occurrence above the main body of clays. They are met with in full force, forming high land, east of Bibra. I have not determined the boundary in this direction.

Flora.

The flora of the Kota-Maleri group, as it at present stands, is represented by only a few species of plants discovered at the following localities:—

From Anáram, opposite to Kota—

Palissya conferta.
Cheirolepis Muensteri.

From Naogaon, in the valley of the Jangaon river, and 9 miles east of Jangaon village—

Palissya Jabalpurensis.
Araucarites Kachensis.

From between Móhár and Balánpúr, 12 miles west of Jangaon village—

Palissya conferta.
Cheirolepis Muensteri.

From Chirákúnt, 4 miles south of Jangaon—

Tæniopteris, sp.
Ptilophyllum acutifolium.
Cycadites, sp.
Palissya, comp. *conferta.*
Palissya, sp.

Of the fossils from Chirákúnt, which were obtained during the early part of this year (1877) and have only been recently examined by Dr. Feistmantel, he says—

"The fossils from Chirákúnt, as far as I can determine or correlate them at present, are—

FILICES.

"*Angiopteridium* (*Tæniopteris*) sp. About 3 leaflets of a very slender form, with well-marked midrib, and thickish, dichotomous secondary veins, passing almost horizontally out of the midrib. The same form is as yet only known in the Ragavapuram shales, and reminds one of *Tæniopteris Daintreei*, McCoy, from mesozoic rocks in Victoria and Queensland, which is an *Angiopteridium* also.

CYCADEACEÆ.

"*Ptilophyllum acutifolium*, Morr., the common form.

"*Cycadites*, sp.—a leaflet belongs to this genus and is of the Ragavapuram type.

CONIFERÆ.

"*Palissya* comp. *conferta.*—There are pretty numerous branches of a conifer, which, I think, belongs to this type of the Rájmahál group, and Sripermatúr group (= Ragavapuram beds).

"*Palissya* sp., a different species."

Associated with these plants, I found some casts of a bivalve shell, resembling an *Unio.* Dr. Feistmantel was unable to determine it.

By reference to Mr. King's table of strata (Rec. G. S. I., Vol. X, part 2, page 56), it will be seen that the Ragavapuram shales, which overlie the Rájmahál group (Golapili sandstones) near Golapili on the lower Godávari, are placed as the equivalents of the Kota-Maleri group. That the beds in which the Chirákúnt fossils occur do belong to the Kóta-Maleri group is a point in regard to which I myself have no doubt. In the neighbourhood of Idlára there are the unmistakable red clays with lenticular layers of greyish-green granular argillaceous sandstones,[1] and sandstones with clay galls, of the Kota-Maleri group. Thence to the south, as far as the range of hills capped by trap, there is no interruption to the series; and, at a short distance up the north face of the range and about a mile and a half east of Chirákúnt, soft, pale yellow, fossiliferous shales occur that yielded the few species of ferns, cycads, and conifers, &c., which were enumerated above.

Dr. Feistmantel's conclusion as to the age denoted by the flora bears out the determination made by myself in the field.

Amongst the plants at Chirákúnt there is one conifer, *Palissya conferta,* which occurs at Anáram in sandstone under the Kota limestone bed. Hitherto it has been considered a very characteristic form of the Rájmahál series,[2] but if the Chirákúnt beds are the equivalents of the Ragavapuram shales, and the Ragavapuram shales are younger in age than the Golapili sandstones or Rájmahál group, the vertical range of *Palissya conferta* is increased. If, on the other hand, its restriction to the Rájmahál group be maintained, then an alteration in the classification of the rocks must be made. The more reasonable view, however, is, I presume, to admit the wider range of *Palissya conferta.*

The same plant was discovered in 1872 by Mr. Fedden, between Móhár and Balánpúr, west of Jangaon, in sandstones which I have included as Kota-Maleris. These sandstones (that is, those in which plants occur) are very like in appearance to the Golapili sandstones, in which *Palissya* is found. Mr. Fedden, speaking of these Balánpúr beds, says, "They consist of fine softish sandstones, in parts silty, and with ferruginous bands and layers, the latter having plant-like flutings and hollow, wood-like casts, so characteristic of some of the upper jurassic beds of Kach. Moreover, some of the ferruginous bands have septaria-like intersections. The few specimens of *Palissya* and isolated leaflets that were found occurred in the finer silty sandstone." Mr. Fedden, it may be noticed, alludes to an upper jurassic likeness; and more than once in his manuscript report for the season 1871-72, when describing different portions of the geology of the Jangaon river valley west of the town, he adverts to the circumstance. Whether these Móhár-Balánpúr *Palissya* beds are like the Golapili sandstones, or like the upper jurassic rocks of Kach, there is no doubt that they constitute a part of the Kota-Maleri group.

The shales and sandstones near Naogaon (in which I last year discovered *Palissya Jabalpurensis* and *Araucarites Kachensis*) are also components of the

[1] These are very characteristic beds of the Kota-Maleri group.

[2] See Palæontologia Indica, 1877, Ser. II, 3, Jurassic (Liassic) flora of the Rájmahál group from Golapili (near Ellore), South Godávari District, p. 183.

group. They may be higher in the series than the Móhár-Balánpúr beds, their plant forms suggesting this surmise. I cannot adduce any stratigraphical evidence that bears upon the relationship of the Naogaon and Móhár-Balánpúr or Chirákúnt beds, for sections are of the most broken and uninstructive character throughout the whole of the valley of the Jangaon river. The rocks that appear are sufficient indexes of the group, but they are inadequately exposed for nice determinations of stratigraphical questions. A look at the map will tell rapidly and clearly the extent of area that I include under the head of Kota-Maleris. The names of localities invested with most interest are printed in block type, and it is easy to note their relative geographical positions. The conclusions regarding the Kota-Maleri group and their distribution are—

1.—That they overlap the Kámthis, but are not directly unconformable to them.

2.—That the red clays and sandstones of Maleri, and the red clays and sandstones above the limestones of Kota, are conformable members of the same group, undistinguishable lithologically, and presumably containing like reptilian remains.

3.—That the Kota fish beds, and the Maleri fish and reptilian beds, belong to the same group.

4.—That the plants of Rájmahál type in the Anáram sandstones (*Palissya conferta* and *Cheirolepis Munsteri*) and the plants from the Chirákúnt shales, are from the same rock group.

5.—That the affinities of the plants are with the upper Gondwána, rather than with the lower Gondwána flora.

V.—*Chikiála Group.*

On the left side of the Pránhita, there is a range of hills near Chikiála, which attracted the attention of Mr. King and myself when encamped at Énchápali, as it was apparent that they were made up of thick sandstones, differing from those constituting the Kota-Maleri group. On examination, we found the scarp that we ascended made up of heavy conglomerates with a large percentage of ferruginous matter, ferruginous glassy-looking sandstones, and soft sandstones with thin iron bands. The general colour is brown, as might have been anticipated from the fact of so much iron entering into the composition of the rocks. The conglomerates contain many fair-sized pebbles 3″ or 4″ to 6″ long. Some of the sandstones present a mammillated weathered surface, a feature that reminded Mr. King forcibly—when taken in connection with their lithological character—of the rocks which in the lower course of the Godávari he has classed as upper jurassic (Tripetty group).

The Chikiála rocks extend across the Pránhita in a north-west direction, and I traced them as far as the river that flows near Bibra. Throughout there is a strong development of ferruginous matter, either in the form of bands of varying thickness or in concretionary masses, or as scattered colouring substance. Fragments of foreign rock in the sandstones are also common. The iron ore worked by the smelters of the country is derived almost entirely from the Chikiála group.

The main development of the Chikiála group is in the Pránhita region; but overlying the Kota-Maleris near Balánpúr is a small thickness of rocks that I would include as members of the Chikiála series. The discovery of coal of jurassic habit is the chief element of distinction; otherwise, I should scarcely have felt warranted in limiting the Kota-Maleri upper boundary at any bed but that in contact with the intertrappeans or trap. The coal occurs in irregular strings, in a clay shale, of which 5 feet are exposed. Above, is yellow, soft sandstone, obliquely laminated at the top, and containing fragmentary carbonaceous markings. The upward section for a short distance is obscured, and then intertrappean and trap beds follow.

It is only in this one locality that I have ventured to map beds of a higher horizon than Kota-Maleris beyond the limit of the Pránhita valley, but in two instances, along the southern side of the Jangaon river valley between Chirákúnt and Belgaon, I noticed a sandstone with ferruginous concretions that would have passed muster as a Chikiála sandstone. I am simply following Mr. King's lead in placing the rocks at Chikiála as a group distinct from the Kota-Maleris.

NOTES ON THE GEOLOGY OF KASHMIR, KISHTWAR AND PANGI, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

INTRODUCTION.

DURING the past summer I have been engaged in examining the rocks of a considerable portion of Kashmir, and of the valley of the upper Chináb, as far as British Lahúl. A great portion of the area traversed has been entirely new ground in a geological point of view; while other parts have been those which remained between the various lines of section taken by the late Dr. Stoliczka, and by the survey of which these various lines have been brought into connection with one another.

Although I have been able to color in a considerable portion of the map, yet the results obtained from the season's work are not in every instance quite so exact as I could have wished, owing to the fact that almost all the strata described, with the marked exception of the carboniferous series, are unfossiliferous. This absence of organic remains compels us, in referring the different rock-groups to their proper geological horizons, to depend on purely stratigraphical evidence; and in some cases this kind of evidence is but uncertain. It must, therefore, be clearly understood that probability plays a certain part in the correlation of some of the disconnected rock-groups.

It may, perhaps, here not be out of place to call attention to the extraordinary absence of fossil remains in so many of the Himalayan formations. This absence is equally noticeable in the silurian slates of the Pír Panjal and Kashmir, in the equivalent slates and limestones of Pangi, and in the older Tertiary deposits of the outer hills. In the still older gneissoid and micaceous rocks, traces of fossils might have been expected to have been, to a great extent, obliterated by subsequent metamorphic action; but even among these older metamorphic rocks there are

many beds of comparatively little altered slates and shales which ought to have retained traces of organic life had such lived in the seas in which these rocks were deposited. I think that we cannot but conclude from the absence of fossils in so many deposits, so favorable to their preservation as are the limestones of the Kiól and Krol groups, that parts of the old Himalayan seas, strange as the fact may appear, were from some yet unknown cause, over wide areas unfavorable to any great developement of animal life.

As the country traversed by me consists of several semi-distinct lines, I have thought it best to treat of these several lines or sections under distinct headings, following in this respect the example set by the late Dr. Stoliczka in his memoir entitled "Geological Observations in Western Tibet."[1] This method has many obvious advantages, although it is open to the objection of necessarily involving a certain amount of repetition.

The survey of a wider area has necessarily led to certain modifications of some of the views expressed in my previous paper on the "Geology of the Pír Panjal;" in the main, however, the conclusions there arrived at as to the ages of the different rock-groups have been maintained.

I have here to offer my thanks to Mr. Drew, late of the service of the Maharajah of Kashmir, for the gift of notes and sections taken by him in various parts of Kashmir territory, and which have afforded me several important pieces of information, as well as suggestions in classifying the different rock-groups.

I.—The Tertiaries and Post-Tertiaries of Kashmir.

The so-called Karewahs of Kashmir have already been treated of by several writers, among the best known of whom are General Cunningham in his "Ladak;" Major Godwin-Austen in the "Quarterly Journal of the Geological Society of London;"[2] and Mr. Drew in his "Jummoo and Kashmir Territories."[3]

During the early part of last spring I proceeded along the Kashmir side of the Pír Panjal range, for the purpose of tracing the boundaries of these deposits.

Along the greater part of the north side of the Pír Panjal, after leaving the older rock-series, we come upon beds of either clays, sands, gravels, or conglomerates, which have the normal north-westerly strike of the Himalaya, and a north-easterly dip varying from five to twenty degrees. Mr. Drew has noticed the occurrence of these beds at page 211 of his above-quoted work, and I have already referred to their presence at Báramúla in the "Records of the Geological Survey of India."[4]

At Báramúla these Tertiary beds consist of yellowish clays and conglomerates, with an average dip of about ten degrees; the same conglomerates are also developed in great force to the north-east of the latter place, where they are still more tilted, and where they have a very great resemblance to the upper conglomerates of the Siwalik series of the outer hills. The blue clays and yellow

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[1] Mem., G. S. I., Vol. V, p. 337.
[2] Vol. XX, p. 383.
[3] Pp. 207, 166.
[4] Vol. IX, p. 162.

sands can be traced to the north as far as Shalúra. To the south-east of Báramúla, almost up to the town of Shapiyan, the lowest beds of these deposits consist of stiff blue clay, with the same dip and strike, the conglomerate beds being generally either absent or replaced by clay; the conglomerates, however, reappear at Hirpúr on the Pír Panjal road. Major Godwin-Austen has noticed that these conglomerates and sand beds at the latter place are several hundred feet in thickness; and he has obtained from them many existing species of terrestrial and fluviatile shells, as well as scales of fishes.

If we follow these highly-tilted clay and conglomerate beds towards the centre of the valley of Kashmir as we can well do along the main road from Gulmarg, where they are greatly developed, we shall find that as we advance towards Srinagar the dip of the beds gradually decreases, until it is not more than a very few degrees from the horizontal; while at the same time the conglomerates and blue clays disappear and are replaced by light-colored sands and loamy clays, bearing very distinct marks of stratification. Finally, as we get within a few miles of Srinagar (beyond which place these deposits have been denuded away), we find that the strata are almost, if not quite, horizontal.

It is, therefore, apparent that we have been crossing the strike of a continuous formation, the lower beds of which are tilted and often conglomeritic, while the upper beds are nearly horizontal and sandy or clayey. There is no sign of any break in this formation that I can detect, and I should think that at a low estimate it cannot be less than one thousand feet in thickness.

Turning now to the opposite side of the valley, and taking the section near Pampúr as a typical instance, we find here also a considerable thickness of stratified clays and sands which are perfectly horizontal; these seem to correspond to the topmost sandy beds on the opposite side of the valley. Mr. Drew says (*sup. cit.*, p. 209) that similar beds to the north of Islamábád attain a thickness of from 250 to 300 feet. Below these sandy beds, north of the latter place, there occurs a considerable thickness of limestone conglomerate, resting conformably on a sloping surface of the carboniferous limestone, and itself sloping also, according to Mr. Drew, at an angle of from seven to fifteen degrees.

The whole of the horizontal sandy deposits to the north-east of the valley, together with the upper sandy deposits of the south-western side, I propose to call the upper Karewahs; while the tilted clay and conglomerate beds along the Pír Panjal I shall designate as lower Karewahs. There is no evidence to prove that the conglomerate underlying the upper Karewahs at Islamábád is contemporaneous with that of the lower Karewahs at Báramúla, and I am inclined to take Mr. Drew's view that it formed an ancient lake beach, and was deposited on a sloping shore.

On the south-western side of the valley of Kashmir it is quite clear from the presence of the tilted Karewahs that a very great disturbance has taken place along the Pír Panjal range since the period of the deposition of these Karewahs; this disturbance has elevated the beds of the lower Karewahs to an angle of more than twenty degrees in certain places, but it does not seem to have extended inwards to the centre of the valley of Kashmir. It is important to notice that the strike of this disturbance coincides in direction with the strike of

the disturbance which has raised the Siwaliks of the outer hills into their present position; the Karewahs, however, differ from the outer Siwaliks in that the dip of the beds inclines away from, instead of towards, the adjoining range.

This tilting of the Karewahs, together with the great amount of denudation which they have subsequently undergone, serves to indicate that these deposits are, relatively speaking, of very great age; and I am inclined to think that, at all events, the lower Karewahs cannot be much, if at all, newer than the upper Siwaliks of the outer hills, and that therefore they probably belong to the topmost pliocene or pleistocene period. I am the more inclined to adopt this view, because we know that in the outer hills the period of disturbance did not extend to the epoch of the Post-Siwalik deposits, which are in all cases horizontal; and it seems to me most probable that the same general disturbance acted as well on the Kashmir Tertiaries and Post-Tertiaries as on the Siwaliks, but that it may perhaps have lasted a little longer in the former area.

Mr. Drew has already pointed out the distinction between the modern alluvium of Kashmir and the Karewahs, and he has also shown that, at all events, the greater part of the former was deposited before the date of the construction of any of the ancient buildings of Kashmir, but how much before we do not at present know; as far as this evidence goes, it all points to the great age of the Karewahs.

I do not here propose to enter into the question of the mode of deposition of the Karewahs, as this has already been discussed by General Cunningham, Mr. Drew, and others; I will, however, here mention that I think there can be no doubt but that the above writers are perfectly correct in assuming that these deposits have been formed in the bed of a vast lake which once covered the whole of the valley of Kashmir.

Below Báramúla, the valley of Kashmir is now bounded by a low ridge entirely formed of fluviatile deposits; this ridge evidently forms the remnant of much larger deposits, which once extended lower down the Jhelam valley, but which have subsequently been removed; it seems, therefore, clear that the old lake must have extended lower down the Jhelam valley than the present boundary of the valley of Kashmir, until it was stopped by some dam. It is not improbable that this old dam existed in the narrow gorge through which the river now flows at Rampúr, some ten miles below Báramúla, this gorge having been deepened out since the Karewah period. At page 171 of the "Wanderings of a Naturalist in India" Professor Leith-Adams appears to consider that the Báramúla gravels were formed by a glacier which dammed Kashmir at this place. The regular stratification of these gravels appears to me to be against this view of the case.

There does not now appear to be any trace of Karewah deposits remaining in the Jhelam valley between Báramúla and Rampúr; these having been all removed and replaced by more recent river deposits,—another proof of the age of the Karewahs.

I am not sure to what extent the Karewahs formerly extended up the eastern end of the valley; at the present time (as is shown on the map) the whole of the country about Sagám is covered only by modern river alluvium, generally above the level of river deposit, which is at once distinguished from the Karewahs by

the absence of str atification. Lower down in the valley, as at Kailgám, the modern alluvium still exists in considerable force, but the yellow and blue clays of the Karewahs are exposed in the river sections; still further west, as near Shapiyan, the Karewahs generally form the surface soil, though near the river valleys they are often covered with a boulder deposit of more modern origin.

II.—THE OLDER ROCKS OF THE SOUTH-EAST OF THE VALLEY OF KASHMIR.

In my previously published notes on the geology of the Pír Panjal, I have already given some account of the rocks composing that range, more especially those on the outer side; in that paper, following former writers, I assumed the probability of the Cambro-Silurian age of these rocks. I may now state that during the present season's work the same rocks have been traced across the valley of Kashmir, and have been there incontestably proved to be in great part of Silurian age, though some of their lower beds may be Cambrian. In the present account these rocks will generally be referred to as the Panjal or Silurian series.

Before commencing the description of these rocks in the Kashmir valley it may be as well to state here, that wherever the word *slate* occurs, it is used in the wider sense, not implying distinct cleavage. I may also mention here that in the map accompanying my paper on the "Geology of the Pír Panjal," the Panjal rocks are referred to as "crystalline schists," whereas they should have been referred to as slates and amygdaloids.

It may also be not out of place here to refer shortly to the amygdaloidal rocks of the Pír Panjal and other parts of Kashmir, before proceeding to describe any of the sections; this is the more advisable, because in my previously-quoted paper on the geology of the first-mentioned region, I discussed the question as to the volcanic or metamorphic origin of these rocks, a question which I then left still in great part *sub judice*, though I inclined somewhat to the theory of their metamorphic origin.

If our researches were confined to the Pír Panjal range, we should, I think, have but little prospect of arriving at any very definite conclusion as to the mode of formation of the rocks in question, since in that region these rocks always occur interstratified with the slates, and their composition is often such that we cannot in the field predicate either their igneous or metamorphic origin. If they be trappean, they must be, as will be gathered from my former paper, of contemporaneous origin with the slates, and therefore we are debarred from any evidence which might have been afforded by dykes as to their trappean origin.

On the north-western side of the valley of Kashmir, however, near Srinagar, and in the Sind valley, there exists a formation which agrees with the series of the Pír Panjal, in containing certain amygdaloidal rocks very much resembling those of the latter region. These amygdaloidal rocks of the Sind valley, however, differ in their association from those of the Pír Panjal; instead of being interstratified with slates, as in that range, and the whole series showing a markedly stratified appearance, these rocks are mingled with a compact greenstone-like rock, and with another granular greenish rock, like anamesite; the greenstone-like rock frequently contains large pear-shaped nodules of chalcedony, and small needles of a mineral, which is, I think, chrysolite. The whole formation is entirely

devoid of any signs of visible stratification, and forms bold massive cliffs, very different in appearance from the slates of the Pír Panjal.

I cannot but think, both from the physical appearance, and from the composition of these rocks (and more especially from the presence of chrysolite and nodules or amygdala of chalcedony) that they are, in great part at least, of eruptive origin; although some of their upper beds may have been brought into their present state by the aid of metamorphism.

Assuming then the, at all events, partly eruptive origin of these Sind valley rocks, it remains to see what relation they bear to the thin-bedded amygdaloids of the Pír Panjal. Now, these presumably eruptive Sind valley rocks underlie the carboniferous limestone; they do not, however, penetrate into this limestone, which must have been the case were they intrusive trap; we can, therefore, only presume they are of contemporaneous origin with the rock series with which they are associated,—that is to say, that they are of *infra*-carboniferous age, or of the same age as the upper slates and amygdaloids of the Pír Panjal range. It may be observed in passing that, even regarding these rocks as eruptive and contemporaneous, it is remarkable that no case of intrusion should have been observed in connexion with them. This important evidence is wanting to finally decide the question of their origin.

The rocks of the upper Panjal series must be therefore contemporaneous with the trappoid rocks of the Lower Sind valley, and if, as seems to be the case, the latter be of eruptive origin, it would seem probable that some of the amygdaloids of the Panjal are likewise of eruptive origin, although there is a gradual transition from the typical amygdaloids to the slates, which, in some cases, may perhaps be due to the effect of metamorphic action, or to the original commingling of detrital and eruptive matter.

On the eruptive hypothesis of the origin of the amygdaloids in the two areas, it remains to be considered why in one area they are associated with slates and in the other with rocks of more decidedly igneous characters. Now, I think the most probable explanation of this difference is that in the upper Panjal period, there were a number of small and intermittent flows of trap in the area of the Pír Panjal range, and that deposition of mud went on regularly in the intervals between these flows; moreover, these flows of trap seem to have been too thin to have produced greenstone-like rocks, all of them being more or less amygdaloidal or vesicular, and indicating no great pressure from above. In the greater part of the Sind valley area, on the contrary, there seems generally to have been exceedingly little trap poured forth among the slate series which underlies the carboniferous limestone, but in the Lower Sind valley and near Srinagar we have a vast mass of trap which was poured forth immediately before the deposition of the carboniferous limestone, and which seems to have been extremely local, since higher up the Sind valley (—*infra*) we find pure slates underlying the carboniferous limestone. This Lower Sind valley trap was of such thickness as to have produced greenstone-like rocks in its lower portion, where the pressure was greatest; while in its higher portion, where the pressure was of course far less, we find amygdaloidal and vesicular rocks, like those of the Pír Panjal; mingled with rocks which may be altered slates.

According to this view, the massive trap and trap-like rocks of the Sind valley are only amplifications of the thin-bedded trap of the Pír Panjal, and both are the equivalents in time of the simple slates which in many other places underlie the carboniferous limestone. This identification of the two trappoid rocks is, of course, independent of any theory as to their origin.

In many other parts of Kashmir and the neighbouring districts trap-like rocks are found in greater or less force among the Silurian slates, but never extending up into the carboniferous period. It is impossible to indicate all the occurrences of these trap-like rocks in a small-scale map, and by means of the necessarily imperfect survey which is all that can be attempted in these somewhat difficult regions. Where, however, these rocks occur in considerable force, they are indicated by crosses in the slate series; no attempt has, however, been made to distinguish between the thin-bedded amygdaloids of the Pír Panjal, and the massive greenstone-like rocks of the Lower Sind valley and Srinagar.

The interstratified amygdaloids of the Pír Panjal, taken together with the peculiar conglomerate referred to in my previous memoir on that range, afford us valuable aids in recognising those rocks in other districts. These amygdaloids are most abundant on the outer sides of the Pír Panjal range, and in the neighbouring parts of Kashmir also extend into the Wardwan valley and into Kishtwar, where, however, they are in much less force, the slates and sandstones there predominating.

Specimens of these varieties of the trappoid rocks of Manasbal near the Lower Sind valley have been forwarded to Colonel McMahon, who has made sections of them for microscopic examination, some of which, together with his notes, he has kindly sent to the Indian Museum; it is from these notes that the following observations have been compiled. The specimens sent comprised a finely porphyritic rock, which will be designated as A; a compact rock, which, we will call B; and an amygdaloid, which we will call C.

Colonel McMahon considers that A is undoubtedly igneous. Crystals of white felspar occur abundantly in this rock, having their axes turned in all directions, in a manner which is very characteristic of trap-rocks. Since its igneous liquefaction, this rock has been altered by aqueous metamorphism; this is rendered evident by treating the rock in the matrass, when on the application of a moderate heat (very far short of a red-heat) it readily gives off water. When thus treated this rock also gives off an acid vapour; it also answers to the silver test for sulphides, and therefore probably contains iron-sulphide, though crystals of this mineral (pyrite) were not satisfactorily observable under the microscope. The other results of the metamorphism which has taken place subsequently to the cooling down of the rock are clearly visible. Masses of green chlorite are very prominent here and there, while the felspar crystals, which seem originally to have been pure triclinic prisms, are now clouded with flocculent, chloritic matter, which has impaired their pristine translucency; even now, however, under the polariscope, polychroic tints are here and there distinctly displayed. The clouding of the felspar crystals due to metamorphism has nearly obliterated all traces of the twin-crystals of the triclinic system, but portions of these seem to be still

remaining in some of the sections, if we may judge by the parallel bands of color, (so characteristic of the triclinic felspars) which appear in certain of the crystals. This rock fuses readily into a bead, and contains 54·1 per cent. of silica.

The rock designated as B appears to consist of an iron-silicate disseminated in thick, flocculent masses through a felspathic base; it shows no traces of a crystalline structure; and it may be a trap or it may be an altered slate. The iron-silicate in this rock does not appear to be hornblende, since the whole of its coloring matter is extracted by hydrochloric acid. This rock also contains a considerable amount of hydrous minerals, which readily give off water in the matrass, on the application of a moderate heat; it contains 62·9 per cent. of silica, 30 per cent. of alumina and iron. a considerable quantity of lime, and a small quantity of magnesia. As far as its chemical composition goes, there is therefore no reason why this rock should not be a trap; the absence of distinct crystalline structure is somewhat against this view, though Colonel McMahon mentions that certain rocks from Edinburgh described as basalts do not exhibit crystalline structure. Colonel McMahon suggests that it is not impossible that this rock may be a sub-aqueous volcanic product, such as ashes deposited in the form of mud on a sea-bottom, or the product of the sub-aërial erosion of trap.

The amygdaloidal rock C according to Colonel McMahon appears to be a trap, since it shows the same quaquaversal arrangement of the felspar crystals which was observed in A; this peculiar structure Colonel McMahon considers could not be produced by aqueous metamorphism. As was the case with A, this rock also shows abundant signs of subsequent metamorphism, patches of chlorite occuring in many places in the crystals; the rock was probably at first a porous or scoriaceous, igneous product, and has been subsequently altered by the infiltration of extraneous substances through its pores.

The above observations of Colonel McMahon on the Manasbal rocks are of great importance; from these observations it appears to be pretty evident that at least some of these rocks are of igneous origin, and it is further evident that all of them have been altered by subsequent metamorphism. The resemblance of the amygdaloids of the Pír Panjal to those of Manasbal, which we have already referred to, renders it probable that some of the former are also of igneous origin. A greater amount of subsequent metamorphic action in one part of Kashmir than in another, would account for the discrepancy in the character of the rocks which so often occur. Thus at Manasbal this metamorphic action appears to have been of great force, and has not improbably merged both slates, trap-ashes, and perhaps true traps into a homogeneous rock like B, which is intercalated with, and in the mass indistinguishable from, true trap rocks like A and C; in the Pír Panjal, on the other hand, the metamorphic action has been less strong, and has not generally altered the slates, except perhaps occasionally near the amygdaloids, into a rock resembling trap. In the one area the whole rock-series looks like an igneous rock, and shows no signs of stratification; while in the other the igneous rocks occur generally as thick bands in the aqueous, and the series taken as a whole consequently shows very distinct signs of stratification. Intermediate states of metamorphism, coupled possibly with a greater or lesser eruption of ashes, would account for the condition of rocks which, like those of parts of the

upper Lidar valley, are intermediate in character between those of Manasbal and those of the Pír Panjal.

We may now continue our survey of the Panjal series, which, in my already-quoted paper of that region, we had traced across the range to Báramúla. Travelling along the foot of the north side of the range from the latter place towards the east, we find that the rocks consist of blackish slates, with a few bands of white quartzite, and others of little altered green or greyish sandstones. Further to the south-east, near the village of Poshgar, the amygdaloidal traps interstratified with slates are in considerable force; these rocks have a south-westerly dip and the normal north-westerly strike which prevails along the whole of this side of Kashmir; the south-westerly dip continues along the range as far as the town of Kúlgám; a little to the east of this place, near the village of Gúndpúra, we come upon a north-easterly dip, which is the continuation of the anticlinal and synclinal axes which were noticed in my previous paper as occurring to the south-west of the Banihal pass, and which cross the range into Kashmir at its bend to the west of the pass.

Throughout the above-mentioned area the Panjals maintain their normal character, consisting of slates and amygdaloids with some sandstones; the amygdaloids are, however, less prevalent to the eastward than in the centre of the range. The matrix of these amygdaloids is nearly always of a compact texture, and green in color: the amygdala are generally greenish-white in color, but are sometimes green, of a darker hue than that of the matrix; the amygdala are too hard to be scratched by the knife, and in places undoubtedly pass into nodules of chalcedony. Near the village of Gúndpúra the amygdala are generally quartzitic or chalcedonic in character; these are usually pear-shaped, and often as much as three inches in diameter.

In the bed of the river flowing from Gúlmarg, as also in the Yechari, and other streams, pebbles of gneiss, similar to that found to the south of the Banihal pass, are of common occurrence; this affords us proof that the same band of gneiss extends along the Pír Panjal range to the westward of the latter place, although I have not yet had an opportunity of tracing its boundaries.

I have already mentioned, in my previous paper, the occurrence of a band of conglomerate on the south side of the Panjal range. In a section taken by Mr. Theobald across the Mohun pass, this band was found *in situ ;* it occurs at a considerable distance above the gneiss, apparently somewhere near the middle of the Panjal group.[1]

Taking now a section across the Pír Panjal pass to the outer hills, we find the following series of rocks. A little above the village of Hirpúr we leave the sandstones and conglomerates of the lower Karewah series, and come upon a series of green rocks with very indistinct stratification; some of these rocks are amygdaloidal, and from their resemblance to the upper amygdaloidal trap of the

[1] I may here mention that Professor Leith-Adams, at page 214 of his "Wanderings of a Naturalist in India," speaks of the finding by a native shikari of an ammonite near the village of Tortiana on the Panjal. I cannot but think that this specimen was not authentic, as we have very good reason to believe that the whole of the Panjal rocks are palæozoic. The specimen was probably derived from the triassic rocks of the opposite side of the valley of Kashmir.

opposite side of the valley of Kashmir, must probably, as we have seen, be considered as of eruptive origin; it is, however, in many cases extremely difficult to decide in this region whether certain of these green rocks are of eruptive origin, or whether they are metamorphosed sedimentary rocks.

Proceeding further up the Hirpúr valley, and approaching the old Mogul halting place of Dubchi, we find these amygdaloidal rocks underlaid by black slates with a north-easterly dip; at Dabchi itself there is a small anticlinal and synclinal fold in these slates. Above Dabchi we have a continuous descending series of slates mingled with a few bands of conglomerates which contain quartzitic and slate pebbles, till some distance below Aliâbad serai, where we find buff and white quartzites underlying these slates; near the latter place we again come upon black slates which underlie the quartzites: these slates contain rounded and angular masses of gneiss. Immediately above Aliábad serai we come upon granitoid gneiss underlying the black slates with the same north-easterly dip; the gneiss includes a few bands of slates and quartzites.

This gneiss continues nearly to the summit of the Pír Panjal pass, and bears to the north-west, along the ridge of the Chitta-Pani and Chota-Galli passes. Near the Pír Panjal pass the beds of the gneiss are almost vertical; still nearer the summit of the pass we come upon black slates with imbedded gneiss pebbles apparently underlying the gneiss, and, again, similarly underlaid by whitish quartzites which form the summit of the pass. On the south-western side of the pass we have a regular series of rocks with a north-easterly dip apparently underlying the quartzites; these consist of slates, sandstones and conglomerates similar to those of the opposite side of the pass, only that the latter rocks are in greater force on the south-eastern side. These slates and conglomerates continue nearly to Baramgalla, where we find amygdaloidal rocks interstratified with the slates: these slates and amygdaloids continue with the same north-easterly dip till we come upon the limestone rocks of the Suran river, which have been mapped in my previously published paper on the geology of the outer side of the Pír Panjal range.

From the above description it will be apparent that on the north-east side of the Pír Panjal we have the following series of rocks, counting from the highest to the lowest, *viz.*:—

1. Greenish slates and sandstones and amygdaloidal rocks.
2. Black and green slates with brown sandstone conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
4. Black slates containing pebbles of gneiss and quartzite.
5. Granitoid gneiss with occasional bands of slate and quartzite.

If now we turn to the rocks on the southern side of the gneiss, we shall find that they present the same series, only in the reverse order; the uppermost rocks of the north-eastern side being the lowest on the south-western side, and *vice versâ.*

This section therefore seems to be only explicable in the same manner as that across the Banihal pass (of which I gave a diagram in my previous paper), namely, by the inversion of all the strata on the south-western side of the range. The

gneissic strata must, therefore, form a great anticlinal axis conformably underlying the slates on either side; this gneissic ridge, however, is not altogether continuous, as it does not occur in the gorge at the bottom of the Jhelam valley, where the slates, much contorted, form the whole section, and apparently bend round the masses of gneiss existing in the hills on either side of the valley.

According to this view the limestones of the Suran valley, which I presume to be inverted, are, as I supposed in my former paper, the topmost beds of the Pír Panjal series, and are probably, as I shall show subsequently, of carboniferous age![1]

The presence of gneissic pebbles in the Panjal conglomerates must probably be accounted for by transport from other outcrops of gneiss, as the gneiss of the Pír Panjal is conformable to the overlying slates, and could not have been denuded at the time of the deposition of the latter.

Having now traced the slates and amygdaloidal rocks of the Pír Panjal range along the greater portion of the south-western border of the valley of Kashmir, we may cross to the opposite or north-eastern side of the valley, and proceed with our survey. Taking the city of Srinagar as our starting-point, and proceeding thence to the neighbouring hill called the Takt-i-Suleiman, we find that the rocks on the western side of that hill are massive, and without any stratification, of a greenish color, and either homogeneous or amygdaloidal; the same rocks also form the small hill on which is built the fort of Hari-Parbat. These rocks are the same as those which we have already referred to in the Lower Sind valley, and which we shall again have occasion to refer to, and, as we have seen, are probably to a great extent of trappean origin.

To the eastward of the Takt-i-Suleiman, we come upon a band of black and green slates, which, towards the north-west of Zebanwan station, is overlaid by calcareous sandstones, cherts, and slates; near the Nishat Bagh these rocks have a northerly strike and dip towards the trap-like rocks which compose the main range to the north-east; the sandstones contain imperfect fossils, but too broken for identification.

I think that the lower slates near the Takt-i-Suleiman, from their resemblance to other rocks, belong in all probability to the Silurian or Panjal period, while the overlying calcareous and arenaceous rocks have a great resemblance to the lower carboniferous rocks of the Marbal pass, which we shall subsequently discuss, and may very possibly be the equivalents of these rocks, though in the absence of any definite proof to this effect, and for reasons to be noticed immediately the rocks are all of one color in the map.

Now comes the question as to the relation of these slate rocks to the trap: we have already seen that the former dip towards the latter, and we have also seen that the latter in the Lower Sind valley underlies carboniferous rocks, and is consequently of high Silurian age; this would tend to show that the slaty rocks

[1] In my former map of the Pír Panjal region the limestone series is not represented as occurring to the north of Rajaori; I, however, now find that this is incorrect, as limestone bands do occur there, mingled with the slates at the apparent base of the series, which belong to the same zone as the more massive limestones to the east and west.

are not of upper Silurian and carboniferous age, as otherwise they ought to overlie the trap conformably, but that they may be of lower Silurian, and have been brought into their present position by faulting, which would well explain the relations of the two. I can, however, at present say nothing certain on this somewhat difficult point.

Proceeding from Srinagar towards the south-eastern extremity of the valley of Kashmir, we find that the same trap-like rocks form the spurs bounding the Pampúr valley; the upper part of the valley to the north of the latter place is occupied by a lenticular mass of carboniferous limestone, with a north-easterly dip, and which apparently overlies the traps, though the relation is in places disturbed by faulting.

I am not sure as to the nature of the northern boundary of this mass of carboniferous limestone, but I fancy that it is a faulted one. Beyond the limestone we again have trappean rocks, underlaid to the north-east by slates, which we shall subsequently trace from the Lidar to the Sind valley.

It may be well to state here, before going any further, that in the Lidar valley the slate series is overlaid conformably by carboniferous rocks, and must consequently be of silurian age. In the Sind and Nowbúg valleys, moreover, the same slates will be shown to be the equivalents of those of the Pír Panjal, the latter also being consequently of silurian age; these slates of Kashmir will therefore often be referred to as Panjals.

At the mouth of the Lidar valley the silurian slate series is interrupted along the axis of the valley of Kashmir by carboniferous rocks; to the north of the latter rocks, however, the slates are continued; their eastward extension will be discussed in subsequent sections.

The carboniferous rocks of the south-east of the valley of Kashmir occupy an irregular ellipsoidal area in the midst of the silurian slates and trap-like rocks: to the westward the former rocks are bounded by the alluvium of the Lidar valley, where we shall again refer to them in the section from Islamábád; there is a small outlier of the older rocks at the latter place. The valley of the Arput river has cut a wide gap in these rocks, to the eastward of which they recur at Achibal, where, as well as at Islamábád, they dip at a low angle to the north-east; another ridge of the same rocks runs near Sháhabád, and disappears to the north-west beneath the alluvium of Kashmir; the beds on the south-western side of this ridge have a north-easterly dip, while those on the opposite side dip to the south-west.

Towards the south-west these carboniferous rocks extend as far as the northern flank of the Banihal range, where I have already referred them in my "Notes on the Geology of the Pír Panjal." At this junction they have a south-westerly dip, and are faulted against rocks of the Panjal series with a north-easterly dip. To the eastward the carboniferous ellipse extends a short distance beyond the Marbal pass, where it will be again referred to in the section from Kishtwar to Kashmir. The north-eastern boundary is very irregular; in the Arpút valley it occurs between the villages of Watúsú and Kor and then bears across to Nowbúg; here the Panjal rocks cut into the middle of it from the south-east; and the inner boundary is a continuation of the line of the Tansan river from

the village of Wyl; from the latter place the Tansan river forms the boundary between the carboniferous and Panjal rocks, as far as the village of Prúma, from whence the boundary again sweeps towards the north-east, and thence again southwards to the Marbal pass.

It will be clearly understood from the above, that the carboniferous rocks of the valley of Kashmir, are, except to the westward, bounded by rocks of the Panjal series; and it may be well here to make a few remarks on the carboniferous series of the valley of Kashmir.

The ridge to the north of Sháhabád, on which stands the station of Hazrat-Ziarat, offers a fair section of the carboniferous limestone, which is here selected for description; the rocks composing this low ridge have a north-easterly dip of about forty-five degrees; the lowest beds exposed consist of dark blue limestone often containing crinoid stems in considerable abundance; in the higher beds this limestone gradually assumes a cherty character, till finally, at the summit of the ridge, it passes into a compact and fine-grained sandstone, of a brownish-yellow color. To the north-east of this ridge there occurs a synclinal axis running through the topmost sandstones; in this synclinal the sandstone is in places almost white, with minute red ferruginous specks.

Passing further to the north-east, we find, at the foot of the ridge to the north-east of the town of Ságam, an anticlinal axis, which brings into view beds still lower in this series than any of those shown in the Hazrat-Ziarat ridge. The beds at the foot of the first-mentioned ridge have a south-westerly dip, while those further on dip towards the north-east. The lowest beds consist of dark-brown sandy shales, gradually becoming calcareous, then containing distinct nodules of limestone, and finally passing into the characteristic dark blue, carboniferous limestone, with crinoids and other fossils. The underlying shales have frequently a bacillar structure; the exposed beds below the limestone have a thickness of about sixty feet, but their base is not visible; these beds are readily distinguishable from those which overlie the limestone, by being more shaly, less compact, and of a darker and duller color; they contain no traces of fossils. The series may be tabulated as follows from above downwards:—

1. Yellowish and whitish sandstones.
2. Blue limestone.
3. Shales, with limestone nodules.
4. Shaly sandstones.

Whether the whole of the four groups of beds noticed in the above table should be referred to the carboniferous series I am unable to say, as no fossils have been found here either in the highest or the lowest beds.

With regard to the highest beds, which are often replaced by banded limestones, I can only say that they very probably represent some of the triassic beds which overlie the carboniferous limestones in other areas, but that, in the absence of fossils, we cannot be sure of this. Some of the underlying shales may very probably belong to the upper Panjal or Silurian series.

It may not, perhaps, be out of place here to mention the springs of water which, at Vernag, Achibal, Bowan, and Islamábád, burst forth from the bases of

cliffs of the carboniferous limestone. These springs are of such volume as to form small rivers at their origin, and take a considerable part in forming the waters of the upper Jhelam. At the two first-mentioned localities the springs rise from the base of cliffs situated at right angles to the strike: while at the two latter they rise from true escarpments. It seems difficult to account for the welling up of such great volumes of water, without calling in the aid of faults, although the relation of the rocks to neighbouring outcrops does not lend much countenance to this hypothesis.

The rocks at the north-western extremity of the valley of Kashmir I have at present only partly examined. To the north of Srinagar as far as the Sind valley, I have not surveyed the rocks: the rocks of the valley beyond the Sind river will be found described in the Amrnath and Sind valley section.

III.—Section from Islamábád to Amrnath, and from Palgam to Sind Valley and North-West Kashmir.

Passing up the Lidar valley from Islamâbád, we have, on the left bank of the river, rocks of the carboniferous series, as far up as the village of Hútmorú; at Bowan these rocks consist of dark blue limestone, with a north-easterly dip; above Bowan there are several flexures, and slates and sandstones are mingled with the limestones. North of Hútmorú we come upon rocks of the Panjal or silurian series, consisting of chloritic slates and sandstones, with a few amygdaloids; their dip is at first north-east.

These Panjal rocks continue as far as the village of Eishmakâm, where they are overlaid conformably by a series of green and white sandstones, blue limestones, and then by blackish slates and sandstones. The limestones contain crinoid stems, and two genera of corals very closely allied to the genera *Zaphrentis* and *Cyathophyllum;* the overlying slates and sandstones are full of *Fenestella, Productus,* and *Spirifer,* of carboniferous species. The series at Eishmakâm may be tabulated as follows, from above downwards :—

1. Slates and sandstones with *Fenestella, Productus,* and *Spirifer*	Carboniferous.
2. Sandstones and dark blue limestones with corals and crinoids	
3. White and blue sandstones	
4. Blue or green slates and amygdaloids=	Silurian.

This section proves the silurian age of the slate series of this part[1] of Kashmir, while the next section will show that these slates are the same as those of the Pír Panjal. It will be observed that the carboniferous rocks of Eishmakâm have precisely the same relationship to the Panjal series as have the Kiol series of the outer hills to the same rocks; the two overlying series are also very similar in mineralogical composition. In my "Notes on the Geology of the Pír Panjal," I suggested that the Kiol group was of upper silurian

[1] It may be well to observe here that in the more eastern Himalayas, there is no distinct Devonian period; and the same rule is held to prevail here. Similarly we may notice the absence of any distinct permian period in the more eastern Himalayas, and probably also in the more western; *vide infra.*

age; the present section, however, makes me think that it must be of carboniferous age.

The carboniferous rocks of Eishmakám continue nearly up to the village of Bhatkot, where we come upon a bold escarpment of amygdaloidal and greenstone-like rocks, which seem to be faulted against the carboniferous rocks, cutting them out to the south-east along the ridge on which stands Liwarpatar station. Above the traps we have rocks consisting chiefly of massive blue and green sandstones and some amygdaloids; as these traps are overlaid by slates, and are not in close relation to the carboniferous series, they may probably be somewhat lower in the series than those of the Sind valley and Pír Panjal. To the west of the Lidar river, the carboniferous rocks seem to be faulted against the trap of Churn station.

The Panjal slates continue nearly as far as the village of Palgám; near the latter place we come upon another outlier of carboniferous limestones and slates, overlying the Panjals; on the Shisha-Nag road to the south-west of Praslung the Panjals again come in beneath the carboniferous limestones, which have here a northerly strike and westerly dip. The Panjals here consist chiefly of slates and bluish-green slaty sandstones, partially metamorphosed.

The same Panjal rocks continue to Chandanwari, where they have a north-easterly dip, and underlie the white sandstones and dark blue limestones of the carboniferous series, which here stretches in a south-easterly direction below the Shisha-Nag into the Wardwan valley; the Panjals in places contain a few beds of amygdaloids interstratified with the slates.

Taking a direct section from Chandanwari across the strike to Amrnath, *viâ* the Koun-Nag, we find that the dark blue carboniferous limestones (containing corals and crinoids) are interstratified with thick beds of slate and sandstone, and continue nearly up to Aston-Marg; at the latter place bands of white dolomitic limestones become common, and beyond this the series consists of almost pure white dolomite with the same north-easterly dip up to the Koun-Nag; here we find the dolomites overlaid by light blue limestones, sandstones, and slates; further in still (to the west of Panjtarni station) the strata consist entirely of slates and sandstones overlying the limestones; near this place the strata are greatly disturbed by contortions. Further north, however, to the south of Panjtarni halting-place, we again come upon strata of white dolomite, with a south-westerly dip, which immediately underlie the slates and sandstones of Panjtarni station without any intervening limestones; these slates will consequently be the highest of the series in this district.

Taking the road to Amrnath *viâ* Nag, we find that to the north of Panjtarni the strike of the white dolomites has become due north and their dip due west; about a mile to the east of Nag, the dolomites are overlaid conformably by slates and sandstones, the former with a bacillar structure. These slates and sandstones are continuous with those of Panjtarni, and to the west of Amrnath cave strike into the Zoji-la pass, where they form the "bacillar sandstones" noticed by Dr. Stoliczka at page 349 of "Observations in Western Tibet."

The dolomites strike through the station and sacred cave of Amrnath and appear again on the Dras road to the north-east of the Zoji-la pass, and are

here continuous with rhæto-triassic strata, described by Dr. Stolickza, which we shall again refer to. To the east of Amrnath we have a descending series of limestones and dolomites; these rocks are more blue in color, to the west, and may probably be in part carboniferous.

The dolomites and limestones to the south of Panjtarni station also bear round to the north, and seem to be continuous with the triassic limestones and slates described by Dr. Stolickza, on the Kashmir side of the Zoji-la.

In a section from Shisha-Nag to Panjtarni, we have much the same rock-series as from Chandanwari, except that immediately below the slates of Panjtarni station, the dolomites are mixed with sandstones, slates, and light-blue limestones, in place of being nearly homogeneous as at Aston-Marg.

As to the age of the above strata, we have seen that the slates and limestones of Chandanwari are carboniferous; the strata above this blue limestone do not contain recognisable fossils, but belong in all probability to the triassic period.

The dolomites of Amrnath are continuous with the dolomitic limestones north of the Zoji-la, which Dr. Stolickza considers as equivalent to the Para limestone. The similar dolomites to the south of Panjtarni, which we have seen are partly replaced to the eastward by limestones and sandstones, will consequently be of the same age, and, as I have said before, seem to be continuous with the undoubted triassic limestones to the south of the Zoji-la.

There now only remains the question of the slates and sandstones of Panjtarni, and the sandstones of the Zoji-la; the latter were considered by Dr. Stolickza to underlie the triassic limestones and consequently to be of carboniferous age; it, however, appears that the section was not clear, and we must consider it to be a case of inversion, since we have seen that these slates and sandstones most distinctly overlie and occur in a trough of the dolomites which occur to the south-east of the Zoji-la. As before said, therefore, these slates must be the highest beds of the rhæto-triassic series.

The dolomites to the north-east of the Zoji-la, according to Dr. Stoliczka, overlie the triassic limestones; the same limestones must therefore be represented to the east of Amrnath; while still further east I think the underlying strata must be carboniferous; these lower rocks would sweep round to underlie the triassic beds of the Dras river.

The strata of pure triassic dolomite are easily recognised from great distances by weathering into the most fantastically-shaped pinnacle crags; this is particularly well shown near Amrnath cave.

Returning now to Palgám, we have to continue our section to the north-west into the Sind valley; immediately to the north-west of Palgám, the limestones and slates of the carboniferous series continue as far as the village of Arú, where they are faulted against the silurian slates, and where they bend round to the eastward to join the Praslung boundary.

From this point to the Sind valley at Kúlan, we have a succession of chloritic sandstones and grey and black slates of the silurian series, intermingled with a few bands of amygdaloidal trap, with a north-easterly dip to the north of Lidarwat, and a south-westerly dip to the southward of this place. These silurian rocks continue as far as the north side of the Kolahoi range, beyond

which we again come upon the limestones of the carboniferous and triassic series, which, beyond Harbagwan, bend round with a west-north-west strike.

In the Sind valley to the north of Kúlan, the silurian rocks gradually entirely lose their chloritic and amygdaloidal character, and consist of black and greyish slates; a little to the south of Gaggangan these slates are succeeded by massive dark-blue limestones, with blue and white sandstones at the base, which, from their position, must undoubtedly belong to the carboniferous series, and which are doubtless continuous with the rocks of the same age and character to the north of Kolahoi. It is not improbable that some of the slates to the south of Gaggangan may also belong to the carboniferous series, though I have placed the boundary at the limestones as being the only distinct line.

These limestone rocks continue as far as the ridge on which stands Shalian station, at the base of which we come upon a fault; the rocks composing the latter ridge have a north-easterly dip, and at the base consist of amygdaloidal traps, overlaid by chloritic rocks, which are probably of metamorphic origin.

These rocks are probably of silurian age, and seem to have been thrust up in the middle of the carbonifero-triassic rocks (as we shall see immediately); I cannot, however, be certain as to what position they occupy in the former series; we have seen that the top of the silurian series which immediately underlies the carboniferous limestone of Gaggangan does not contain any trap, and it is therefore hardly likely that these rocks, irrespective of their position, are the same as those slates. I think it more probable that they belong to some lower silurian zone, which has been subsequently brought into its present position by faulting; this may, however, be a case of a local trap outflow and subsequent metamorphism of the upper slates.

This band of trap and silurian rocks continues to the south-east, forming the high range below Sonamarg; on the northern side of this range we come upon beds of light blue and banded limestones, white dolomites, and slates having at Thajwaz a south-westerly dip, and which seem to be faulted against the silurians. To the north of the last-mentioned village these limestone rocks have a north-easterly dip, and form a continuous ascending series to the northwards, where they are overlaid by sandstones and slates, similar to those of the Zoji-la and Panjtarni station; tracing these latter rocks along the ridge towards the Zoji-la, we find that they are inverted in several places, which accounts for Dr. Stoliczka's supposition that they were older than the limestones.

The Thajwaz banded limestones are very different from the massive dark-blue limestone of Gaggangan; from the fact that Dr. Stoliczka found a triassic ammonite almost at the base of the former series, it is clear that at least the greater part of the rocks to the north of the silurian band must be of rhæto-triassic age, and I have accordingly so colored them in the map.

To the east of Sonamarg, I have traced these triassic rocks up the Nichinai stream into the Kishenganga watershed; their distribution in the latter district must, however, be reserved for a future season's work.

Returning now to Kúlan, we have to follow the Sind river into the valley of Kashmir. Green and grey slates, with some bands of amygdaloids, and of the very characteristic conglomerate of the Pír Panjal, continue to the village

of Mamar; the occurrence of this conglomerate in the slate series of this side of Kashmir proves them to be the equivalents of the slates and traps of the Pír Panjal. On the right bank of the Sind river these slate rocks seem all to have a north-easterly dip; on the left bank, however, an anticlinal axis occurs below the village of Rewil; there is probably, therefore, either a break or a concealed fold among the rocks of the right bank.

Some little distance below the last-named village, we come upon an entirely different series of rocks; on the right bank of the river we find at the base of the cliffs (the dip being to the north-east) a considerable thickness of coarse gneissic rocks followed by unaltered grey sandstones, massive blue limestones, and overlaid by slates. The relation of these rocks to the silurians on the north-east is not well seen, but I think a fault divides them.

To the north-west and north these rocks are apparently faulted against a mass of what seems to be trap-like rocks, which we have already discussed. These trap-like rocks form a band extending from the east of Safapúr station towards Haramúk; similar rocks occur on the left bank of the Sind valley, but the exact division between these and the silurian slates is there also in great part concealed by forest.

At the northern side of the extremity of the spur, which forms the right bank of the Sind valley, we come upon dark blue massive limestones, which overlie the trap-like rocks, their strike being north-westerly, and their dip north-easterly. These limestones extend a little to the north of Safapúr station; to the west of this ridge we again come upon trap-like rocks, where a peninsula of these rocks extends into the middle of the limestone, and the latter has a quaquaversal dip around the trap.

To the south of the lake of Manasbal, at Aha-tang station, we have another mass of greenstone-like rock showing through the limestones; these limestones at and near Kandabal overlie the compact blue limestone, and consist chiefly of white dolomitic beds, which are identical in character with those of Amrnath, and which, I have not the least doubt, are likewise of triassic age. The massive blue limestone has not yielded characteristic fossils, though it contains crinoids, and brachiopods, and has yielded a species of *Orthoceras* to Mr. Theobald's search; there can, however, be not the slightest doubt from its character and position beneath the dolomitic beds, that it must be considered of carboniferous age.

The position of the presumably trappean rocks beneath the carboniferous limestone, shows that if the former be non-intrusive, they must be *pre*-carboniferous; while, on the other hand, if they be intrusive, they must be *post*-carboniferous.

From the form of their occurrence in a dome-shaped mass beneath the limestones, it might be supposed at first sight that these trap rocks were intrusive: the absence, however, of all dykes penetrating the limestone seems to forbid this view; and we can only conclude, as I have said before, that they are non-intrusive rocks, and are the representatives of the more thin-bedded amygdaloidal traps of the upper slates of the Pír Panjal.

We must now revert for a moment to the gneiss, sandstones, and limestones which occur between the trap-like rocks of the Sind valley, in order to endeavour

to find out their age. I must, however, first observe that the carboniferous series of Kashmir is liable to great variation in mineralogical composition, even in contiguous areas. Thus, we have seen that at Islamâbâd this series consists almost entirely of limestones; at Eishmakám, limestones are comparatively scarce, and sandstones and slates the prevalent rocks; while again at Palgám and Shisha-Nag, limestones predominate.

Now, it will be observed that these sedimentary rocks of the Lower Sind valley, if we except the lower gneiss, are almost identical in composition with the carboniferous rocks of Eishmakám; and I think it possible that they both belong to the same period; the lower gneiss beds would be the representatives of the sandstones of Eishmakám, which have been altered by some subsequent metamorphic action; which, as we have seen in the case of the trap-like rocks, has been strong in this area.

It is, I think, perfectly clear that these rocks cannot belong to the silurian series, in which limestone never occurs, nor do I think from their composition that they belong to the older gneiss, though Mr. Drew apparently favors that view.

In conjecturally referring them to the carboniferous period, however, a difficulty occurs, in that they are so different in mineralogical character to the neighbouring carboniferous limestones of the valley of Kashmir. The only way out of this difficulty, to my mind, is in considering that the carboniferous rocks of Kashmir were deposited in basins in a sea broken up by islets or peninsulas. The rocks deposited in deep water might well be chiefly calcareous, while those deposited in shallows and along the shores would consist of grits, clays, and a few calcareous bands.

This supposition would explain the difference in the two types of undoubted carboniferous rocks of Kashmir; the one exemplified by those of the upper Lidar valley, and Manasbal, and the other by those of Eishmakám. In the former series there is an almost unbroken succession of limestones through the carboniferous and triassic periods, while in the other the upper carboniferous beds are all sandy and clayey, and are not overlaid by trias.

The carboniferous limestones of Eastern Kashmir belong to the former type, though we cannot say for certain that they are overlaid by trias; at the Marbal pass, as we shall see, they are replaced by rocks of the second or littoral type.

The grits, clays, and limestones of the Lower Sind valley, if, as I think possible, they are of carboniferous age, must be the littoral deposits of the basin in which the massive limestones and dolomites of Manasbal were laid down. I cannot, however, be at all certain as to the age of these rocks, and have accordingly left them blank on the map.

Before proceeding to examine the rocks of the region of the Wular lake, it may, perhaps, be well to glance for a moment at the description of the rocks of the Sind valley given by Dr. Stoliczka at page 349 of his "Observations in Western Tibet." In justice to the memory of such an authority, it must, however, be observed, that his notices of these rocks were made on the evidence of a single hurried section, on his return from an arduous journey in Tibet; while my own observations are the result of a far wider survey. It is not, there-

fore, to be wondered at if some of Dr. Stoliczka's conjectural correlations of these rocks require certain modification at our hands.

In Dr. Stoliczka's Memoir, the triassic age of the Thajwaz limestones was proved by the occurrence of a characteristic ammonite; it appears, however, that the Shalian ridge of trap and probably silurian slates was not noticed, but that the Thajwaz limestone was supposed to rest directly on the massive limestone of Gaggangan; the slates underlying the latter were supposed to be of carboniferous age—a supposition which is in part quite likely to be correct, though the lower slates are silurian. The massive chloritic rocks, supposed to be of silurian age, seem to be in part at least the above-mentioned trap rocks, which we also have referred to the upper silurian series; the gneiss and limestones below Marmar are not noticed.

Commencing our survey of the rocks around the Wular lake, we find that trap forms the greater part of the rocks as far as the Budkool river, masses of carboniferous limestone, however, occurring along the borders of the lake, notably at Sadykut, Matipur, and on the left bank of the Budkool river. The limestones usually have a north-easterly strike.

To the north of the Wular lake, the trap-like rocks extend to a little beyond Kahati station, where they are overlaid by black, green and grey silurian slates, and green and buff sandstones, with an east-north-east strike, and north-westerly dip; on the supposition that the trap-like rocks are the highest silurians, this must be a case of inversion.

These slates and sandstones form the mountains surrounding and jutting into the Lolab valley; at Trigumma the green slates with a westerly dip are overlaid by massive blue carboniferous limestone, which forms the spur to the north-west of the latter place: a synclinal axis runs along this spur, and the limestones to the westward are again underlaid by slates: the lower beds of the former alternate on this side with beds of green slate.

The position of the Lolab slates, beneath the carboniferous limestone, shows that the former are of silurian age, and correspond with the slates of the Pír Panjal.

To the west of Shalúra we have various colored slates, white and green quartzitic sandstones, and amygdaloidal traps, all of which, I believe, are interstratified with the sedimentary rocks, and which must therefore belong to the silurian series. The sandstones and slates to the west of the Trigumma limestone are much more altered than those to the east, owing to the presence of the traps in the one area, and their absence in the other. To the south of Shalúra the silurian slates can be traced along the northern flank of the Kaj-Nag range to Báramúla, from whence we have already traced them along the Pír Panjal.

This section, therefore, again proves the identity of the slate series of the two sides of Kashmir, and also their silurian age.

IV.—Section from Kashmir to Maru-Wardwan and thence to Kishtwar.

Starting from the town of Ságám, we leave the semi-ellipse of the carboniferous limestone at the village of Panzgám or Panzgáma, and again come on the slates and amygdaloids of the Panjal series, which we have already traced along

the north-eastern boundary of the valley of Kashmir. At the village of Soap to the east-north-east of Ságam, there are very extensive iron works belonging to the Maharaja; the iron seems chiefly to occur in the form of carbonate and oxide at the base of the carboniferous series; Dr. Ince in his "Guide to Kashmir," when describing these works, mentions also the occurrence of silver and lead at the same place, and I have been shown specimens of the ore of the latter metal said to have been obtained from there.

The rocks of the Panjal series at Panzgám have a north-easterly dip of about fifty degrees and consist in great part of the amygdaloids, intermingled with slates and slightly altered sandstones.

At the village of Shátrú we come upon the semi-detached mass of carboniferous limestone, previously referred to, with a low north-easterly dip, extending as far as the town of Nowbúg, and both boundaries of which appear to be faulted. To the south of the Nowbúg outlier of carboniferous limestone, an anticlinal axis runs through the Panjal rocks, which seems to be continuous with the anticlinal which traverses the carboniferous limestone to the north of Ságam. The Panjal rocks to the south of Nowbúg are chiefly slates.

Between Nowbúg and the Margan pass the Panjal rocks form in the main a regular ascending series, interrupted by several minor flexures; for some distance above Nowbúg these rocks chiefly consist of amygdaloids, mingled with slates, while nearer the pass, slates and quartzitic sandstones are more prevalent; the slates are sometimes banded, but are more usually of a uniform olive-green color, marked with reddish ferruginous spots; at the top of the pass the rocks are mainly whitish quartzose sandstones. Throughout the series there are occasional bands of amygdaloids, while I also noticed numerous fragments of the characteristic conglomerate which has been referred to above as occurring on the Pír Panjal; I did not, however, observe this rock *in situ;* this was probably owing to the quantity of snow which lay on the pass at the time of my crossing.

A short distance to the north-east of the Margan pass a synclinal axis traverses the rocks, which must be high up in the Panjal series, and from thence we have a regular descending section with a south-westerly dip to the valley of the Wardwan river, repeating the series of rocks which occur on the south-west side of the pass.

The quartzose sandstones on and near the Margan pass exhibit very beautiful examples of "broad ripple;" the large slab of nearly white sandstone, which has been placed as a "cairn" on the summit of the pass, is a notable example of this ripple; other examples of rippled-marked rocks, covering surfaces of many square feet, are also exposed on the road between the pass and Inshin, in the slate series; marks which I take to be annelid or molluscan tracks may also be occasionally observed on some of these ripple-marked slabs.

It will be observed that the white quartzitic sandstones which occur high up in the Panjal series on the Margan pass, have a striking resemblance to part of the Kiol series which I have considered elsewhere (Rec. Geol. Surv. Ind., Vol. IX, p. 160) as being probably the top of the Panjal series in the outer hills; the limestone which underlies the sandstones in the latter region is not, however, represented on the Margan pass; it is not impossible that some of these

sandstones really belong to the carboniferous series like that of Eishmakám; in the absence of fossils, however, I have thought best to class them as silurian.

Reverting to our section, we find that at the village of Inshin the Wardwan river follows for a short distance on the course of an anticlinal axis in the Panjal slates, the rocks on the right bank of the river having a south-westerly dip, while those on the left bank have a north-easterly dip. Below Inshin the anticlinal axis, with a north-westerly strike, continues for a short distance along the course of the river, and then, leaving the river, bends down and gains a nearly north-and-south strike. Continuing our course below Inshin along the river, after leaving the anticlinal, we pass for a short distance across beds with an easterly dip; further down the river we cross a synclinal axis, the beds to the eastward of this axis having a nearly due westerly dip. As we proceed to the eastward the rocks, which at first consisted of bluish slates and slaty sandstones, become gradually more and more micaceous and metamorphosed, until we come upon an anticlinal axis of gneiss, with a north-and-south strike, about seven miles above Marú; the gneiss, with mica-schists and micaceous slates or shales, continues in a series of minor synclinals and anticlinals as far as Marú.

To the north of Inshin the Panjal series continues as far as the old fort of Bassman, where those rocks are again underlaid by gneiss.

It will be observed from the above that no hard-and-fast boundary can be drawn between the Panjal series on the one hand, and the underlying gneiss series on the other,—there being a gradual transition between the two. The boundary here and elsewhere between the two series is generally drawn nearest to the first band of gneiss; it will be noticed in the sequel that many thick masses of slaty rocks occur in various places within the gneissic area; in some cases it is extremely probable that these masses of slate should be referred to the Panjal series, they having attained their present position by faulting. In an outline survey, however, conducted in the hasty and imperfect manner in which that of this part of the Himalayas must of necessity be, it is impossible to map in all these outliers.

Returning for a moment to the ripple-marked rocks of Inshin, we may observe that these rocks, which, as we have seen, occur chiefly near the top of the Panjal series, must have been deposited in shallow water, and probably in a subsiding area.

Again taking up our section at the village of Marú, we find that the gneiss continues up the Farriabadi river, with a general northerly strike and westerly dip, for some eight or ten miles, beyond which point I was unable to continue my survey on account of the vast quantity of snow which then filled the valley; in all parts of the valley the pebbles in the stream consisted entirely of gneiss or very similar metamorphic rocks, and it seems to be most probable that the same gneissic rocks extend to the summits of the barren and almost inacessible range from which the stream takes its course. I may, perhaps, here mention that several boiling and sulphurous springs occur about ten miles up the Farriabadi river, and also in several other places of this district.

The gneiss in the Marú district is either fine-grained or porphyritic; in either case indistinguishable in hand specimens from granite; it passes in places into mica-schist, micaceous shales, and even into little altered slate, which latter is

frequently found interstratified with it; in no case, either in this district, or in the rest of the country here treated of, were veins of granite found penetrating the gneiss.

Between the villages of Marú and Hanzá the strike of the rocks becomes first north-westerly, and lower down again almost due north, following in this respect very nearly the course of the Wardwan river; the rocks on both banks have a north-easterly or easterly dip, while an anticlinal axis runs near the summit of the ridge on the right bank. The prevailing rock at Marú is gneiss, while at Hanzá white and massive quartzite is the most common.

At the bend of the Wardwan river, near the village of Lopar the strike of the metamorphic rocks again becomes north-westerly with a low north-easterly dip; an anticlinal and a synclinal fold are crossed in the southerly-flowing portion of the Wardwan river below Lopar; below this synclinal there is a low north-easterly dip, which continues as far as the village of Krur; there is much contortion of the rocks at Lopar. Gneiss is the most prevalent rock in the series of this district, it is generally very massive and granitoid, and most especially at the village of Ekâli; below the latter village the gneiss is underlaid by whitish quartzites very like those before mentioned as occurring higher up at the village of Hanzá.

At the village of Krur we come upon an abrupt junction, apparently a faulted anticlinal axis, with a north-westerly direction; the rocks on the southern side of this faulted anticlinal have a south-westerly dip of about seventy degrees, and consist of black slates with a few felspathic grains, in striking contrast to the gneiss and quartzitic rocks on the north of the same axis; micaceous or black slaty beds continue from this fault to Kishtwar, but no distinct beds of gneiss occur in the rocks immediately to the south of this fault; though another ridge occurs near Mogalmaídán. I have accordingly taken the line of this fault, as the boundary between the crystalloid and the slate series, the latter of which will be shown subsequently to be the equivalent of the lower part of the Panjal series.

V.—SECTION FROM KISHTWAR TO LAHÚL.

We may now proceed to trace the rocks of which we have just been treating further up the Chináb valley into British Lahúl: at the town of Kishtwar itself the rocks are chiefly micaceous or black slates, without any bands of gneiss; an anticlinal axis with a north-westerly direction traverses these rocks a little to the north of the town.

In the sharp bend which the Chináb makes immediately above the town of Kishtwar, the river cuts directly across the strike of the strata; above this bend, however, the river flows towards the north-west, and consequently with the strike. In proceeding up the river from Kishtwar we first cross the above-mentioned anticlinal, and subsequently a synclinal axis; the rocks are either micaceous or black slates with a few sandstones, either grey or whitish in color; as we advance further up the river the rocks become gradually more and more crystallised and metamorphosed; till at the village of Pías they are chiefly massive quartzites passing locally into gneiss; the lowest beds exposed in the ravines at and near this place are of gneiss. This gneiss corresponds to that of the Ward-

wan valley; and the boundary between the crystalline and slate series has consequently been drawn a little to the south of the last-mentioned village.

Near the village of Galha the river cuts obliquely across an anticlinal axis; this axis appears to be the continuation of the faulted anticlinal axis occurring on the Wardwan river at Krur, to which we have already referred; it does not, however, appear to be faulted here; the same anticlinal continues its course along the foot of the range to the south of the Chináb in an easterly direction, as far as the town of Atúlí, where we shall again have occasion to refer to it.

Between Pias and Seri or Sereri, the rocks consist of granitoid gneiss, mica-schist, and micaceous slates; the lower parts of the tilted beds are frequently more altered than the upper parts of the same beds; at Seri itself the rocks are almost entirely granitoid gneiss: further up, at Jar, white quartzite is more common, and there are various kinds of rocks intermediate in character between these two; a boiling spring occurs a little above the last-mentioned village.

At the junction of the Bhútna with the Chináb river we find a great variety of metamorphic rocks, among which we may mention gneiss (fine-grained, porphyritic, or garnetiferous), mica-schist, micaceous slates, garnetiferous shales, quartzites, black slate, with crystals of felspar, gradually passing into gneiss, and little altered slates and shales.

The anticlinal axis which we have already referred to as traversing the range to the south of the Chináb, crosses the latter river at Atúli, and taking a north-easterly direction runs for some distance up the valley of the Bhútna river, where it appears gradually to die out. The strike of the rocks on the southern side of this anticlinal gradually changes, till at Atúli it becomes north-easterly, the dip being to the south-east: higher up the Bhútna river the strike again bends round to regain its normal north-westerly direction, the dip being to the north-east. The rocks on the western side of this anticlinal on the Bhútna maintain their north-westerly strike and north-easterly dip, up to the faulted anticlinal.

In addition to the evidence of faulting afforded by the different strike of the rocks on either side of the Bhútna anticlinal, we have further proof in the distinct mineralogical composition of the rocks on the two sides of the river. The rocks on the right bank of the Bhútna at Atúli are black slaty shales, highly impregnated with sulphur and iron; higher up the river these rocks are succeeded by garnetiferous schists and granitoid gneiss: as far up as the village of Machail the rocks are chiefly granitoid gneiss, which appears to extend up to the Umasi-la. The rocks on the left bank of the river at Atúli consist of micaceous schists and shales abounding in garnets, and of thick-bedded granitoid gneiss.

I myself have not crossed the Umasi-la into Zanskar, but I learn from Mr. Drew's notes that the gneiss rocks continue across the pass into Zanskar, as far as the village of Ayting, where they are overlaid by silurian slates, as has already been determined by Dr. Stolickza. It seems, therefore, probable that the whole of the great snowy range separating the Chináb valley from Zanskar consists of one great core of gneiss.

I also learn from Mr. Drew's notes that a few bands of pure white crystalline limestone occur interstratified with the gneiss in certain parts of the valley of the Bhútna river.

Leaving now the Bhútna river and again continuing our course up the Chináb valley, we find, in consequence of the curving of the above-mentioned anticlinal, that the latter river above Atúli cuts at first almost directly across the strike of the strata, through beds of garnetiferous mica-schist, shales, and gneiss. At the village of Sol, however, the strike has regained its normal north-westerly direction, following nearly the course of the river, the dip on either side being to the north-east. A little to the westward of the village of Patrali, the strike once more becomes almost directly north and south, and consequently nearly at right angles to the course of the river; near this change of strike we cross firstly a synclinal, and then a curved anticlinal axis; the strike above the latter becoming a little to the north of west, with a southerly dip on both banks of the river, the same strike and dip continues as far as Kilar; the rocks consist chiefly of mica-schist, micaceous shale and granitoid gneiss with bands of slate; at the village of Darwas a rock much resembling coarse pegmatite occurs apparently interstratified with the gneiss; below the former there is a thick band of a white felspathic rock containing large trihedral prisms of tourmaline. Immediately to the south of Kilar there is a very thick band of granitoid gneiss; this gneiss is overlaid conformably by a newer series of bluish slates and sandstones, which we shall now trace for a considerable distance, and which contain no truly metamorphic rocks. These newer slaty rocks will henceforth be designated the "Pangi slate-group."

Following these Pangi slates up the Chináb river, we find that at Sauch the slates are thick-bedded with occasional bands of splintery greyish shales; the strike at the latter place has changed to the north-west, with a south-westerly dip. At Saor we cross a synclinal axis in nearly vertical slates, which again cuts the river higher up, to the westward of the village of Sheli; above Saor there are a considerable number of bands of blue and fawn-colored sandstones mingled with the slates which here are nearly black and thick-bedded, or flaggy. Taking a cross section through the same rocks to the south-west of Tindi, we find that there is a descending series with a north-easterly dip across the Drati pass, beyond which I presume we should again come upon the underlying metamorphic rocks. Between Tindi and Margraon the Pangi slates contain large quantities of iron ore, partly in the form of the magnetic oxide; sandstones and occasional bands of blue limestone alternate with the slates. Through the thick-bedded black slates at and near the village of Salgraon, there are scattered a vast number of imbedded blocks of granitoid gneiss, either angular or water-worn, and varying in size from less than an inch to upwards of three and a half feet in diameter. These gneiss blocks extend through a vertical rock-thickness of at least two thousand feet and also occur over a very wide horizontal area, being found, though in smaller numbers, in the same beds near the village of Saor, some ten miles lower down the river; by following the Salgraon beds towards the south-east the same blocks might probably be traced a considerable distance in that direction also.

The occurrence of these blocks of gneiss in the Pangi slates proves incontestably that some portion at least of the older gneissic rocks must have been upheaved and undergoing denudation at the period of deposition of the slates, and that consequently such gneiss must have undergone its metamorphism previously to the deposition of the slates.

With regard to the transporting power which brought these gneiss blocks into their present position, there can, I think, be but little doubt that it was either ice or the roots of trees descending some old river. From the vast number of these blocks, together with the large area over which they extend and the great thickness of rock through which they occur, I am strongly inclined to think that the former agent must have been the transporting power, however improbable it may appear that ice should once have floated in a sea so near the tropics. We must, however, remember that there is a somewhat parallel case in the ice-worn boulders of the Talchir group in India itself. If the supposition as to the origin of these boulders, here put forward, be tenable, it is evident that the old gneissic land must have formed elevated mountains, and the temperature of the climate was sufficiently low to admit of glaciers descending to the sea-level and bearing away with them rock-masses. I may add that the nearest gneissic mass to the erratic block near Salgraon is about twenty miles distant, and that the outer portion of this gneiss is conformable with the slate series, and consequently could not have afforded the blocks.

Continuing our course up the Chináb, we cross the before-mentioned synclinal between Salgraon and Sheli; the north-westerly flowing reach of the river at Triloknath runs along an anticlinal axis, and we come across another synclinal some seven miles above the latter place. Beyond Triloknath the rocks have a south-westerly dip up to and beyond the village of Tandi, where the Chandra and Bagha rivers unite; the rocks have the same general composition in this area as below, though limestone becomes relatively more common.

Following up the Chandra river, we find that the rocks on the left bank, and further up on the right bank also, have a north-easterly dip; these rocks extend southwards to the north side of the Rotang range where they rest conformably on gneiss and other metamorphic rocks; limestones are here common in the series.

The superposition of these Pangi slates and limestones on the metamorphic rocks of Kúlú has been already noticed by the late Dr. Stolickza ("Geological Observations in Western Tibet," p. 340), who considered that the former were probably of silurian age.

Returning now to Tandi, we may trace the same group of slates up the Bagha river till they again rest on gneiss; this gneiss, according to Dr. Stoliczka, commences at the village of Kangsir or Kangsar on the Bagha,[1] and extends as far as the village of Darcha or Daree, beyond which it is overlaid by undoubted silurian rocks. This gneiss on the Bhaga river Dr. Stolickza considers as being equivalent to his so-called "central gneiss."

We must return again for a moment to Triloknath, and from thence ascend the valley to the north of that place, thereby obtaining another cross section of the strata; a short distance up the valley the beds with a north-easterly dip cease, and we come on beds with a south-westerly dip; these beds, which consist of slates and sandstones, form a regular descending series up to the village of Tingrat, becoming gradually more and more micaceous; near the latter village we come upon

[1] By a mistake at line 7 from the top of page 341 of Dr. Stoliczka's above-quoted paper, the word *Chandra* has been substituted for *Bagha*.

bands of gneiss in the slates and further up upon massive granitoid gneiss. The boundary between the Pangi slates and the gneiss must here be considered somewhat arbitrary: it is drawn near the first gneiss band.

To the south-eastward of Chirpat in the same valley there occurs a large irregular mass of granitoid gneiss which extends nearly to the missionary station of Kailing, on the Bagha river, although it does not anywhere touch that river: the exact relations of this mass of gneiss to the Pangi slates is a good deal concealed by permanent ice and snow; it appeared, however, to underlie them, and may doubtless be considered as an outlier of the same gneiss found in mass to the north-eastward.

From the above description it will be apparent that the Pangi slate group forms an irregular ellipsoidal mass resting on a basin of gneiss and other metamorphic rocks.

We have now traced the same series of gneiss and other metamorphic rocks down the Wardwan valley and along the southern side of the greater part of the snowy range which separates the valley of the Chináb from Zanskar, and we have already taken several cross sections in various parts of this range, by which we were led to conclude that the same gneiss extended to its summit, between Atúli and Zanskar; more to the east we find from Dr. Stoliczka's notes that on the Chandra, the gneissic rocks are not more than a few miles in width and are overlaid by presumably silurian slates.

It now remains to consider for a moment the rocks forming this Zanskar (or, as Dr. Stoliczka calls it, Baralatse) range, more to the north-west in the Súrú district. Now, at page 347 of "Geological Observations in Western Tibet" Dr. Stoliczka observes—

"The metamorphic rocks of the Baralatse range, south of Suroo (Súrú), extend to the north of this place with an unchanged mineralogical character up to the village Zangra. Here they carry a large proportion of hornblende, and overlie a mass of gneiss in a dome-shaped bedding. The gneiss, which is very well exposed near the old fort, Carpo-khar, consists of a great quantity of white quartz, orthoclase and muscovite; biotite being rather subordinate. On the northern side it is overlaid by a similar hornblendic schist, which gradually changes into talcose and chloritic schists, these being themselves followed towards the north by micaceous schists. From Sankoo to Saleskoot tough chloritic and quartzitic sandstones prevail, and to the north of the last-named place they are in contact with syenitic rocks."

From this it would appear that the Zanskar (Baralatse) range at this point consists of a core of gneiss, overlaid by less altered metamorphic rocks, and the latter again by the above-mentioned hornblendic rocks, which probably sweep round to the north of Súrú, and separate the metamorphic rocks from the possibly eruptive syenitic rocks to the north.

At page 348 of the same Memoir, Dr. Stoliczka, in speaking of the hornblendic rocks of Sankoo, considers these rocks to be silurians; at page 351 he again remarks that "the gneiss of the prolonged chain, south of Padam and Suroo (Súrú), is the same as the central gneiss, only devoid of the albite granite veins." In the map I have accordingly assumed that the whole of the metamorphic rock

occurring below the hornblendic silurians is the equivalent of the central gneiss of Darcha at the south-eastern end of the range, and the gneiss of Wardwan; the central axis of the range being pure gneiss and the outer parts less completely metamorphosed, precisely as we have found to be the case in the Chináb district; this identification will be again referred to.

I may also observe that I find from Mr. Drew's notes that the hornblendic rocks in the neighbourhood of Dras very much resemble some of the Kashmir amygdaloids, the probability being that those of Dras swing round between the northern extremity of the Súrú metamorphic rocks and the carboniferous rocks of the Zoji-la, to join the amygdaloidal silurians of Kashmir: it will, however, require a tour in that direction to settle this point. To the north of the Dras silurians we gather from Dr. Stoliczka that the syenitic rocks belong to an entirely different series from the gneissic rocks of the Zanskar range.

VI.—Section from Kishtwar to Kashmir.

Returning once again to Kishtwar, we have to carry a section from thence into Kashmir, across the Marbal pass. This line of country has been already traversed by Dr. Stoliczka, who at page 350 of his often-quoted paper on Western Tibet dismisses the subject with the remarks that "to the east of the Marbal pass only metamorphic rocks have been observed all the way to Chamba;" and that "some of these altered rocks are probably altered silurians, but there is every reason to expect that still older formations may be found in them."

The Kishtwar and Kashmir section requires a somewhat fuller examination at our hands than the above, as from it alone are we able to connect the slates of Kishtwar and Pangi with the slates and amygdaloids of the Panjal series.

Between Kishtwar and Mogalmaidán the micaceous sandstones and black and greenish slates which we have seen to occur at the former place continue; the anticlinal axis which runs a little to the north of Kishtwar is continued near the road, and beyond Mogalmaidán its strike bends upwards to the north. The section at and beyond the latter place is somewhat obscured by forest, but it appears probable that the middle of this anticlinal is occupied by a ridge of granitoid gneiss overlaid by slates; to the south-west of Mogalmaidán, we have an ascending series of slates about halfway up to Khashimarg station; the second half of this section being occupied by a descending section of similar rocks, which rest on granitoid gneiss at Pipran station; the latter gneiss seems to be continuous with the gneiss which I have described in my paper on the Geology of the Pír Panjal as underlying the rocks of the Panjal series at Banihal. In the upper half of the slate series between Mogalmaidán and Khashimarg there occur numerous beds of the characteristic Pír Panjal amygdaloids and conglomerate.

Leaving the gneiss beyond Mogalmaidán on the Kashmir road, we pass over an ascending series of slates and amygdaloids, with bands of conglomerate for a considerable distance; an anticlinal axis passing through these rocks near Singpúr; these slates and amygdaloids belong to the typical Panjal series.

Beyond Singpúr we come upon a series of greenish slates and sandstones, with a north-easterly dip, in which about six miles to the east of the Marbal pass, I found a considerable number of specimens of *Productus, Spirifer,* and other car-

boniferous fossils. These rocks are the continuation of the carboniferous series of Kashmir. They appear to be faulted in between the rocks of the Panjal series, from which they are distinguished by the absence of the amygdaloids, so characteristic of the latter, by the slates being thin-bedded and banded, in place of thick-bedded, by the presence of beds of chert or limestone, and by their characteristic fossils, when the latter occur.

The beds with the north-easterly dip continue along the road till we get near to the Marbal pass, where we cross obliquely an anticlinal axis in nearly vertical carboniferous rocks; the same axis continuing into Kashmir and joining with the axis previously noticed as occurring to the south of Nowbúg. A small patch of carboniferous limestone occurs to the south-east of Ail station; and a bed of the same limestone is interstratified with the slates on the left of the road on the eastern side of the Marbal pass. The ridge on which Ail station is placed consists of rocks of the Panjal series, with a north-easterly dip.

On the Kashmir side of the Marbal pass the carboniferous rocks contain more cherty beds, in which fossils are extremely numerous; near Wankringi halting-ground there occurs a thick band of conglomerate in the same rocks; and some of the sandstones are ripple-marked. Below the last-named locality the Panjal rocks, with the same north-easterly dip, bend down to the southward; the Tansan stream forming the boundary between the two series, as far as the village of Wyl, where the carboniferous rocks strike obliquely across the ridge to the north-east of that place, beyond which we have already described them in the section from Kashmir to Wardwan.

The carboniferous rocks to the south of Wyl have a south-westerly dip; north of that village the dip is to the north-east; an anticlinal axis continuous with that before noticed near Sagam running along the ridge to the north of Wyl.

The Panjal rocks to the north-east of the Tansan river are composed almost exclusively of amygdaloids; the carboniferous rocks below Marbal are almost entirely limestones.

From the above it is evident that we must amend Dr. Stoliczka's statement given at page 350 of his "Observations in Western Tibet," that the carboniferous rocks do not extend to the eastward of the Marbal pass (*i e*, if the word *pass* is used in its normal sense to signify the "crest"). The occurrence of limestone and carboniferous fossils six miles to the east is a sufficient proof of this error.

The slaty and sandy carboniferous rocks of the Marbal pass, abounding in fossils, seem to replace the limestones of the valley of Kashmir, and, as we have already seen, may probably be considered as the littoral deposits of the basin in which the limestones were laid down.

VII.—GENERAL CONCLUSIONS.

From a perusal of the facts detailed in the foregoing sections, and from the Memoirs of Dr. Stoliczka, Mr. Medlicott, and myself [1] on the rocks of different

[1] Stoliczka: Mem. Geol. Surv. India, Vol. V.
Medlicott: Do. do. do. do., Vol. III.
Do. Rec. do. do. do., Vol IX
Do. Geology of Kumaon and Garhwal in Memoir on Hill Districts of N.-W. Provinces
Lydekker: Rec. Geol. Surv. India, Vol. IX.

districts in the Himalaya, we may draw the following general conclusions as to the older Palæozoic rocks of our present area, *viz.* :—

That the Pír Panjal range consists of a series of silurian slates and amygdaloids resting on a core of gneiss.

That the same rocks are continued into Kishtwar, where they rest on the gneiss of the Zanskar ridge, and that they also have the same relations in the Wardwan valley.

That the same rocks extend to the eastward, where they rest on the gneiss of the Dhaoladhar range.

That the same rocks recur on the northern side of Kashmir, where they are overlaid by carboniferous and newer rocks.

That the gneissoid rocks of Súrú are continued down the Wardwan valley, extend to Pangi, and are *apparently* continuous with the "central" gneiss of the Bagha river.

That the Pangi slates have the same relationship to the gneiss of Pangi and Kúlú as have the silurian Panjals to the gneiss of Wardwan.

That the slaty rocks on the northern side of the Zanskar range have the same relation to the gneiss as have those on the south side, and that consequently if the gneiss of the two areas be of the same age, the overlying rocks will also be of the same age.

Our next point is to consider how these various rock-groups are to be connected together, and also as to what horizon in the geological series they belong.

Before proceeding further, it will be well to remind the reader that Dr. Stoliczka determined two distinct horizons of gneiss in the Himalaya; one of these kinds of gneiss is to be found on the right bank of the Indus in Ladák, and since it conformably underlies carboniferous rocks is supposed to represent altered silurian strata. The second kind of gneiss was named by Dr. Stoliczka "central gneiss," and according to that author[1] "is overlaid by undoubted silurian rocks," though we are not told whether the overlying rocks are conformable or unconformable to the gneiss. This "central gneiss" was at first supposed to be characterised by being traversed by veins of albite-granite, but as might have been supposed, this turned out to be a somewhat local character. It is not therefore apparent whether the "central gneiss" was supposed to have been gneiss at the time of the deposition of the silurian series or not; if, as I have suggested above, the gneiss blocks which occur in the Pangi slates were derived from the neighbourhood, it is evident that they must have been derived from gneissic rocks, which existed as such at the commencement of the deposition of the Panjals, and which, if the "central gneiss" really conformably underlies the silurians, must be older than the former.

Now, we have already seen that Dr. Stoliczka unhesitatingly recognised the gneiss of Darcha as being "central gneiss," and also that he conjectured that the gneissic rocks of Súrú belonged to the same group, and it is quite clear that the latter underlie conformably the slate series, which we presume to be of silurian age; if this identification be valid, the "central gneiss" must also underlie the silurians conformably.

[1] Geological Observations in Western Tibet, p. 341.

Again, if this hypothesis be correct, the "central gneiss" will be the equivalent of some part of the gneissic series of the northern flanks of the Zanskar range, though it is, of course, quite possible that in those places where there is a transition from slate to gneiss that gneissose beds in one place may correspond to slaty beds in another.

On the other hand, the "central gneiss" is supposed to be the oldest known rock in the Indian Himalayas, and if we consider that this gneiss is the same as the gneiss which underlies conformably the silurian slate series, we should be driven to the conclusion that the gneiss from which the pebbles in the Pangi slates are derived was older than the "central gneiss."

The latter consideration would lead us to the conclusion that the "central gneiss" must be distinct from the gneiss underlying the Kashmir silurians, and that there is a break between the two, the Darcha gneiss really being unconformable to the overlying silurians, and a great portion of the gneiss of the Zanskar range being unconformable to the gneiss which underlies and alternates with the slate series, and being contemporaneous with the central gneiss. I cannot, however, say positively which of these two hypotheses is the correct one; and accordingly all the gneiss in our area has been colored of the same shade.

It seems evident that the gneiss which underlies the Pír Panjal slates is the same as that which underlies the slates of Kishtwar and the Wardwan, and also that which underlies the Pangi slates on the north of the Rotang pass, though we cannot say the same with regard to the gneiss of Darcha.

The gneiss of the Dhaoladhar, if we may judge from its abrupt termination to the north-west, may be the equivalent of the "central gneiss" of Darcha, although in strike it corresponds more nearly with that of the Panjal range.

If it should turn out that the central gneiss be older than the *infra*-silurian or Cambrian gneiss, it will be necessary that the centre of the mass of rocks forming the Zanskar range should be colored of a different tint from the gneiss of the rest of the map, with the exception probably of the granitic mass at Kailing and that of the Dhaoladhar range. Only an arbitrary boundary could, however, in any case be attempted.

It seems, therefore, to be apparent that all the gneiss in the area under discussion is older than the great mass of rocks of the silurian period (with the possible exception of a small mass in the Lower Sind valley), and that in certain instances there is a passage from the conformably overlying slates to the underlying gneiss, in which case the gneiss generally may be called Cambrian.[1] Further, there is evidence of the existence of another kind of gneiss, which existed as such at the silurian period; this gneiss occurs probably in the Zanskar range, but whether or no it is the same as the "central gneiss" we are at present unable to say.

With regard to the overlying rocks, we have seen that the Panjal series is *infra*-carboniferous, and we may therefore consider them (in the absence of any

[1] Everywhere this gneiss is overlaid by a great thickness of slates, which are considered as "silurian;" the conformable gneiss being always below this thickness is called for the sake of distinction Cambrian, though it may, of course, be occasionally in part silurian, or, on the other hand, [illegible] of the slates may sometimes be Cambrian.

fossil evidence) as being silurian; we have traced the same rocks into the Wardwan, and also into the Kishtwar country, and it is probably the same slate series which overlies the gneiss of the Dhaoladhar.

With regard to the slates and limestones of Pangi, we find that they rest upon gneissic rocks in the Kilar district, which gneissic rocks are almost certainly the same as those of the Pír Panjal, which, as we have seen, underlie conformably the silurian slate series; it is therefore probable that the Pangi series is also of silurian age. If, as we have suggested, the Darcha gneiss is older than the Kilar gneiss, there will be unconformability in the junction of the slate and gneiss in the one area, and conformability in the other, which would also lead to the inference that the Cambrian gneiss is totally unrepresented at Darcha, unless some of the lower slates be its equivalent.

The Pangi slates were considered by Dr. Stoliczka, to be in all probability the equivalents of the silurians of Lahúl which "overlie" the "central gneiss;" the silurians of Lahúl are continuous with those of the Padam valley, which, as far as I can gather, overlie Cambrian gneiss on the northern side of the Zanskar range, exactly as do the Pangi slates on the southern side. Although the absence of fossils from the latter group, as far as we know at present, may be considered by some as leaving the question open to doubt, the probability as to their silurian age is to my mind very strong indeed.

We have seen that the valley of Kashmir is bounded generally by interstratified trap and silurian slates, interrupted along the axis and to the north-west by carboniferous limestone, and more massive trappoid rocks; at the north-western end of the valley we have seen conclusively that the carboniferous rocks occupy a synclinal in the silurians and it is probable that they have the same relations at the Marbal pass to the south-east. This would lead us to infer that the axis of the valley of Kashmir lies along a synclinal; the normal relations of the rocks having, however, in several places, been much disturbed.

If we admit the foregoing references, the following table will approximately represent the chronological succession of the palæozoic strata in the area under consideration, as far as we are at present able to classify them:—

Slates of Marbal pass	Carboniferous.
Limestones of Islamábád and Manasbal; slates and limestones of Eishmakám and Lidar valley	Carboniferous.
Slates of Lahúl	Silurian.
Slates and limestones of Pangi	Silurian.
Slates of Kishtwar	Silurian.
Slates and trappoid rocks of Pír Panjal	Silurian.
Trappoid rocks of Kashmir	Silurian.
Gneiss of Pír Panjal	Cambrian.
Upper gneiss of Wardwan and Zanskar range	Cambrian.
Kúlú gneiss	Cambrian.
Central gneiss of Darcha	*Infra*-silurian, but exact age not determined.
Lower gneiss of Wardwan and Zanskar range	*Infra*-silurian, but exact age not determined.
Dhaoladhar gneiss	*Infra*-silurian, but exact age not determined.

I must now say a few words as to certain relationships of some Himalayan rock-groups, which were suggested by Dr. Stoliczka, at page 141 of his "Memoir on the Rocks of the North-Western Himalaya."

It is there stated that the *infra*-Blini sandstones and Simla slates probably correspond with part of the Bhabeh group; if we refer to page 341 of the "Observations in Western Tibet" we find that the Lahúl silurians are also supposed to correspond with the Bhabeh group. The group of silurians in the above table may therefore also be probably referred to the Bhabeh group, with which they agree in overlying gneiss.

Referring again to page 141 of the "North-Western Himalaya," we find that the Blini group is conjecturally correlated with the Muth group; the one overlying the *infra*-Blini (Simla slates) and the other the Bhabeh group.

In the same memoir (page 141) a part at least of the *infra*-Krol group is conjectured to be the representative of the Kuling or carboniferous series, while the overlying Krol limestone is likewise conjecturally correlated with the Lilang or triassic series.

With the two latter correlations I may say at once that I cannot agree, and for the following reasons: firstly, I have already stated at page 161 of my "Memoir on the Geology of the Pír Panjal," my opinion that on account of their composition, position and relation to the older rocks, the Krol and Kiol groups are probably equivalent; secondly, the Kiol group occurs at the top of the silurian rocks (the series being inverted) precisely in the same manner as do the carboniferous rocks to the north of Kashmir; thirdly, the Kiol group agrees precisely in composition with the carboniferous rocks of the north of Kashmir: both groups consisting of massive blue limestone, polychroic slates and sandstones; fourthly, the rocks of the Kiol group are quite unlike the light-blue banded limestones, dolomites, and slates of the north of Kashmir; fifthly, no limestone occurs in the silurian rocks of Kashmir; there is, therefore, a fair presumption that the Kiol group does not belong to that period, while if we refer it to the triassic period, we have no rocks to represent the carboniferous period.

It is, I think, therefore extremely probable that the Kiol group may be of carboniferous age. This being so, and assuming the identity of the Krol with the Kiol group, the former also (and probably the *infra*-Krol group) will be of carboniferous age.

It may be well here to mention that in my above-quoted paper I considered the Kiol group as being probably partly of upper silurian and partly of carboniferous age; I was led to this inference from the fact, that in many parts of the valley of Kashmir itself the junction between the silurian rocks of the Pír Panjal and the carboniferous series is often a faulted one, and I was led from this to think that there was a break between the two which was filled by the lower Kiol beds; other sections, however, to the north of Kashmir, have shown the carboniferous limestones and slates resting conformably on the silurian Panjals, and have shown, as I have said, that the Kashmir silurians contain absolutely no limestone.[1]

[1] At page 161 of my above-quoted paper, the Kiol series is compared to the Kuling series, as regards mineralogical composition; the latter group is there by an accident stated to be of triassic in place of carboniferous age; the similarity in composition of the two series adds some confirmation to the probability of the carboniferous age of the former; in line 14 of page [illegible] of the same memoir the word *Lilang* should be substituted for *Kuling*.

The assumption of the carboniferous age of the Kiol group leads to another modification of the views expressed in my previous memoir. It was there suggested that the great limestone inliers of the Jamú hills were the equivalent of the carboniferous limestone of Kashmir, and were consequently distinct from the Kiol and Krol groups.

I now, however, think it probable that the three groups belong to the same period; the greater prevalence of pure massive limestone in the Jamú hills than along the foot of the Pír Panjal is not greater than in the carboniferous rocks of the valley of Kashmir, over those of Eishmakám; while in one portion of the Kiol series, to the north of Púnch, the strata are almost entirely limestone.

The above propositions being accepted, it will be evident that the Blini series is represented in the upper part of the Panjal series, below the Kiol group.

According to the above views, the following table will represent the equivalent rock-groups in the Simla and Kashmir Himalaya. I wish it, however, to be most distinctly understood that, although the relationships *inter se* of the various rock-groups in the two areas are, with a few exceptions, pretty accurately determined, yet that the correlations of those of one area with those of the other can only be viewed in the light of a probable hypothesis, and not as a fixed fact.

Approximate classification of rock-groups in the Western Himalayas.

KASHMIR TERRITORIES AND LAHÚL.	EAST OF KASHMIR.	AGE.
a { Sandstones and slates of Zoji-la and Panjtarni. b { Upper limestones and dolomites of Amrnath, Sunamarg, Manasbal and Dras river.	Lilang series.	Rhætic and trias.
Limestones of West Kashmir. Blue limestones of Manasbal. Limestones and slates of Marbal pass, Lidar and Upper Sind valleys. Kiol series (?). Great limestone of Jamú hills (?).	Kuling series. Krol limestone (?). *infra*-Krol group (?).	Carboniferous.
Upper Panjal slates, shales and trappoid rocks. Trappoid rocks of Wular lake.	Math series. Blini series.	Upper silurian.
Lower Panjal slates; lower slates and trappoid rocks of Kashmir. Slates and limestones of Pangi Lahúl slates.	Bhabeh series. *infra*-Blini, or Simla slates	Lower silurian and Cambrian (?).
Gneiss of Pír Panjal. Upper gneiss of Wardwan and Zanskar range. Kúlú gneiss.	? ?	Cambrian.
Central gneiss of Darcha. Lower gneiss of Wardwan and Zanskar range. Dhaoladhar gneiss.	Gneiss of Chor mountain	*Infra*-silurian, but exact age not determined.

It will be seen that in this rough and approximate table a gap occurs in the second column between the lower slates and the "central gneiss," which cannot be filled up until the relations of the two in the matter of conformity or unconformity are settled; if they are unconformable, and the "central gneiss" is older than the Pír Panjal gneiss, it may then not be improbable that some part of the Simla slates may be the equivalent of the Pír Panjal gneiss.

Since the above was written I have seen the able paper of Colonel McMahon on the Simla Himalayas.[1] The author is there of opinion that the Simla slates and other non-crystalline series are certainly newer than the crystalline series; he also thinks that the hypothesis of inversion will not explain the case, but that there was an original unconformity between the two series; the slates having been deposited on a denuded surface of gneiss. In the Pír Panjal and in Pangi, I think the latter explanation cannot be adopted, as there is a passage between the crystalline and non-crystalline series. If original unconformity exists in the Simla region, it would tend to confirm my suggestion that there exists gneiss belonging to two periods in these regions; the Simla or "central" gneiss being older and unconformable to the slates, while the gneiss of the Pír Panjal is conformable to the slates, and has been metamorphosed out of their lower beds, and may consequently be in part the equivalent of the lower Simla slates.

It will require another season's work to trace the relations of the triassic rocks of the Zoji-la to the gneiss of Súrú and the Zanskar range, and also, as I have previously said, to trace the former rocks in the opposite direction into the Tilail or Kishenganga valley.

NOTICES OF SIWALIK MAMMALS, BY R. LYDEKKER, B.A., *Geological Survey of India.*

The Indian Museum has again been enriched by a large collection of vertebrate fossil remains obtained from the Siwalik series of Sind and the Punjáb, by Messrs. Blanford, Fedden, and Theobald, and their native assistants. Many of these fossils are, of course, merely duplicates of previously acquired specimens, while others belong either to new genera or species, or illustrate more fully other species whose existence has hitherto been only slightly indicated to us by the evidence of a few fragments of bone, or isolated teeth.

In the present paper I shall shortly notice a considerable number of the more interesting of these specimens, reserving for a future opportunity the figuring, and more detailed description, of the specimens, in the hope that I may then have still more materials to work upon.

Before proceeding further, it may be well to notice certain conclusions which I have lately arrived at respecting the distribution in time of some of the fossils.

It may, I think, be now stated with considerable probability, that, as I have hinted before, the mammaliferous beds of Sind belong to a somewhat lower horizon than that which yields the majority of the fossils in other areas. These mammaliferous Sind beds (Manchhar) overlie the Gáj beds, which seem to be upper miocene, and cannot therefore be much older than the lower pliocene, or

[1] Rec. Geol. Surv. Ind., Vol. X, p. 204.

the very highest of the miocene. Their mammalian fauna is nearest to that of the miocene of Europe, and does not contain, as far as we know, any of the modern forms which occur in the Siwaliks of the Punjáb, which may probably be considered to be higher up in the older pliocene. The occurrence of a large number of mammalian genera which are confined to the miocene in Europe, in the pliocene of India, is paralleled by what occurs according to Professor Marsh in North America, where European miocene mammals occur in the older pliocene.[1]

The mammalian tertiary fauna of Sind is characterized most especially by the presence of great numbers of both bunodont and selenodont pig-like animals, the majority of which are, however, unfortunately only known to us (with the exception of those genera which also occur in Europe) by isolated teeth.

These same Siwalik or Manchhar beds also contain the remains of *Dinotherium* in considerable abundance; in India this genus is elsewhere known only from Kach, Kúshalghar, and Perim Island, from beds which are probably low in the Siwalik series. In the Sind area *Mastodon* and *Hippotherium* are common, and two teeth of the miocene genus *Amphicyon* have also been found there.

Of the modern and existing genera *Euelephas*, *Equus*, *Bos*, *Bubalus*, *Capra*, and *Hippopotamus*, which are so characteristic of the typical upper Siwaliks, I am not aware that any remains have been obtained from the Manchhar beds. The only two living genera of Mammals of which we have clear evidence as occurring in these beds are *Rhinoceros* and *Sus*, both of which have existed since the miocene epoch.

From the still older marine Gaj beds, Mr. Fedden has this year obtained a part of a skull and three upper molars of *Rhinoceros sivalensis;* the specimen was obtained at a considerable distance below the Manchhar horizon, but its precise position, Mr. Fedden tells me, could not be defined, owing to the irregularity of the thickness of the beds in different localities and the absence of the Manchhars at this spot. This *Rhinoceros* is thus proved to have been one of the earliest of the Siwalik Mammals, having lived in the Gaj period.

In the Siwaliks of the Punjáb Mr. Theobald seems to have proved pretty clearly from the sections sent down with the fossils, that in this region the greater number of extinct genera do occur in the lower beds of the series, while the greater number of living genera occur higher up; this idea cannot, however, be thoroughly worked out, owing to the fact that the fossils occurring in one bed are washed out and mingled with those from another. I imagine that this confusion is especially the case with the very few fossils which occur below the great fossiliferous zone, as they are generally picked up by native collectors and mixed with those from other zones. The lower beds, like those of Núrpur and Kúshalghar from which *Amphicyon* and *Dinotherium* have been obtained, are very probably the equivalents of the Manchhars.

Hitherto all, or nearly all, the Siwalik fossils seem to have been found as isolated bones; during the past season, however, Mr. Theobald has discovered a bed at Nikí in the Punjáb, where a vast number of associated bones of many

[1] Address to American Science Institution, New-Haven, 1877, p. 24.

species are found mixed *pell-mell* together; and which probably indicates an old quicksand in which the Siwalik animals were engulphed.

From this deposit I hope that many valuable specimens will yet be obtained, which will throw more light on the affinity of some of the less known Siwalik animals than can be obtained from the study of a few isolated bones or teeth. The bed has already yielded many specimens, among which I may notice the complete cranium of a gigantic pig, part of the cranium with milk dentition of the new trilophodont *Mastodon* and several associated sets of foot bones. Among the latter is a nearly perfect foot of *Hippotherium*, which shews us that the Asiatic species of the genus had precisely the same conformation as the European forms.

I will now mention the most important and interesting of the specimens obtained during the past year; in the course of these notices I shall have to mention several re-determinations of previously noticed specimens; these re-determinations have either become necessary owing to the discovery of more perfect specimens or owing to the errors of previous determinations.

These re-determinations, though of course to be regretted, are almost unavoidable in determining such isolated specimens as are the majority of the fossils from the Siwaliks, and are also made more frequent in the present instance, owing to the extremely unsatisfactory state of the previous literature referring to Siwalik Mammalia.

I may also here mention that Mr. Theobald has collected several bones of Siwalik Birds, and a considerable number of the remains of Reptiles; these, however, will not be further noticed at present, as I have not yet had an opportunity of studying these in any detail.

PRIMATES.

Genus: MACACUS.

Remains of quadrumanous Mammals have been long known from the Siwaliks, and indeed the specimens obtained from those rocks were the first known fossils belonging to the order. These remains, however, are of extremely rare occurrence, the known specimens only numbering some five or six; up to the present time, no specimens of the remains of this order have been obtained among the many hundreds of specimens which Mr. Theobald has forwarded from the Siwaliks of the Punjáb to the Indian Museum. In December last, however, two specimens of the upper jaw of a small monkey were received at the Indian Museum from Mr. Theobald, which had been obtained from the Siwaliks of the village of Asnot, in the Punjáb, and which form the subject of the present notice.

Before describing the new specimens, it may be well to consider for a moment the remains of Monkeys which have been previously obtained from the Siwaliks; the memoirs on the specimens will be found collected in the first volume of the "Palæontological Memoirs," accompanied by a plate.

The first specimen discovered was a part of the right maxilla with the molar series. In speaking of the specimen the discoverers (Messrs. Baker and Durand) conclude by observing: "This circumstance and the differences before pointed out,

clearly separate the fossil from the species belonging to the genera *Cynocephalus* or *Semnopithecus*."—("Palæontological Memoirs," Vol. I, p. 299.) The authors seem here clearly to have considered that the species could not belong to *Semnopithecus*, and not to have assigned it to any genus. The next notice of the specimen occurs at page 7 of Professor Owen's "British Fossil Mammals and Birds," where the following passage occurs: "All these remains were entirely fossilised, and they satisfactorily confirmed the conclusions of Lieutenants Baker and Durand, that a large species of *Semnopithecus* had co-existed with the *Sivatherium* and the *Hippopotamus*." Now, as we have seen, the authors in question, if I understand them aright, expressly stated the distinctness, in their opinion, of the species from *Semnopithecus*.

Apparently from this statement of Prof. Owen, H. von Meyer in the "Index Palæontologicus" (Nomenclature, Vol. II, p. 1133) refers to this specimen unhesitatingly under the genus *Semnopithecus*, and there gives it the name of *S. subhimalayanus*.

In his "Osteographie" (Primates, p. 60) M. de Blainville refers to the specimen, and thinks (if indeed it belong to a Monkey at all) that it is more nearly allied to *Macacus*, and, above all, to *Cynocephalus*, from both of which genera the original describers thought that it was generically distinct, although they observe that "were it not for the size of the canine and the fifth molar, it presents some resemblance to the genus *Macacus*."

From the above it seems to be clear that the specimen in question has no right to the generic title of *Semnopithecus*, though I do not mean to say that it may not belong to it. When the specimen is alluded to under that name, it must be distinctly understood that this is only done as a matter of convenience, and because it has so frequently been referred to under that name.

The next specimen was an astragalus discovered and described by Messrs. Falconer and Cautley, who remark ("Palæontological Memoirs," Vol. I, p. 300): "It (the specimen) corresponds exactly in size with the astragalus of the *Semnopithecus entellus*;" and again: "This astragalus, in conjunction with Messrs. Baker and Durand's specimen, satisfied us of the existence of *at least two* distinct fossil *Quadrumana* in the Siwalik hills."

In the same Memoir these authors also treat of two other specimens which were both fragments of lower jaws containing teeth; one of these jaws was larger than that of *S. entellus*, and belonged, according to Falconer, to "a species of smaller size than the animal to which the specimen described by Messrs. Baker and Durand" belonged; there is no direct statement of the genus of the specimen, though I infer that the authors inclined to think it belonged to *Semnopithecus*. It appears to me to be not improbable that this specimen and the above-mentioned Astragalus may have belonged to the same species.

The other specimen of a lower jaw belonged to an animal intermediate in size between *Semnopithecus entellus* and *Macacus rhesus*; this specimen the authors thought probably belonged to the genus *Macacus* (*Pithecus*); an additional specimen of the lower jaw of the same species was also obtained.

There are therefore three Siwalik species of Monkeys known from the evidence of molar teeth, *viz*., a large species specifically named *subhimalayanus*, and which

is often noticed as a *Semnopithecus*, an intermediate species probably belonging to that genus; and a small species probably belonging to *Macacus*. There seems also to be evidence of another species known from a single upper canine, but this does not concern us at present.

We may now return to Mr. Theobald's specimens; the first of these consists of a portion of the right maxilla, containing the three true molars and the alveoli of the two premolars; the two first molars are slightly touched by wear, while the last ("wisdom tooth") is still in germ, being very late in its time of protrusion. The crowns of the teeth are oblong in shape, and bear on their masticating surfaces four cones placed at the angles of this surface; at either end there is a slight transverse talon-ridge. The first molar is smaller than the second, and the third nearly equals the first, and is somewhat narrowed posteriorly.

The second specimen is an almost similar portion of the left maxilla of a somewhat older, though similarly sized, animal; it shews the anterior root of the zygomatic arch, the last true molar, and the alveoli and fangs of the last premolar and two first molars; each of these teeth was inserted by three fangs. The last tooth of this specimen is exactly like the same tooth of the previous specimen, and shews that both specimens belonged to the same species. The anterior root of the zygoma is placed immediately above the interval between the alveoli of the first and second molars. In the following table the dimensions of the first of Mr. Theobald's specimens are given in the first column (*a*), the corresponding dimensions of *Macacus (Inuus) rhesus* in the second column (*b*), and those of *Semnopithecus entellus* in the third column (*c*):—

	a.	*b.*	*c.*
Length of three molars	0·75	0·86	1·0
" first molar	0·26	0·29	0·32
Width of " "	0·22	0·28	0·30
Length of second "	0·29	0·31	0·35
Width of " "	0·28	0·30	0·36
Length of third "	0·26	0·29	0·35
Width of " "	0·23	0·28	0·35

We have now to consider the question of the genus of the fossil specimens, which we shall find a by no means easy problem, as the teeth of allied genera of Monkeys are so excessively alike one another. *Firstly*, we may say that, from their squared crowns, the teeth in question do not belong to the genus *Hylobates*, in which the molars have rounded angles; *secondly*, that they do not belong to *Cynocephalus*, on account of their small size, and from the last molar being narrowed posteriorly, whereas it is of equal width throughout in the latter genus; *thirdly*, that they do not belong to the genus *Mesopithecus*[1] from the upper miocene of Attica, since the penultimate upper molar of that genus has an accessory tubercle on its external surface, which is wanting in Mr. Theobald's specimens; and, *fourthly*, that they resemble the teeth of *Cercopithecus*, *Semnopithecus*, and *Macacus* (including sub-genera) so closely that they must belong to one of these three genera.

[1] Gaudry: "Animaux Fossiles de l'Attique," pl. I, figs. 6, 7.

The next question, therefore, is to find some character which distinguishes the molars of the three last-named genera. Now, if we turn to page 442 of Owen's "Odontography," we shall find that in treating of the molars of the mandrils, the author observes that the true molars "progressively increase in size from the first to the third;" and on the next page, that "the smaller Baboons, of the genus *Macacus*, repeat on a smaller scale the dental characters of the mandrils." Now, with all due deference to the author of the valuable work under notice, it does not appear to me that the characters given above are always characteristic of the genus *Macacus*, because if we refer to the table of measurements given above (and several specimens have been compared), we shall find that in *M. rhesus* the first molar is smaller than the second, which agrees with Professor Owen's statement, but that the third is smaller than the second, which does not.

In treating of *Semnopithecus*, Professor Owen remarks on page 443 that "the first molar is equal to the second." Now, in the table given above, it will be seen that in *S. entellus* the first molar is smaller than the second; and in the figured specimen of the dentition of this genus given in figure 5, plate 116, of the "Odontography," the first molar is also somewhat smaller than the second.

These characters do not, therefore, seem to be of any great value as affording means of distinguishing between the genera in question.

It does, however, appear that in *Semnopithecus* there is a tendency for the molars to be of more equal size than in *Macacus*, in which the first is always small and the second large; thus in *S. phayrei* and *S. siamensis* the first and second molars are of equal length; while in *S. entellus* and *S. cephalopterus* the second and third are of equal length, and the first slightly smaller. I have seen no instance in the genus *Semnopithecus* in which in the same jaw the first molar is smaller than the second, and the second larger than the third.

In the genus *Cercopithecus* there appears to be great equality in the size of the upper molars; thus in *C. sabæus* the three are of equal length; in *C. pluto* the two first are equal, and the third slightly smaller; and indeed in all the specimens that I have seen the two first are of equal length.

It is therefore apparent that the fossil specimens cannot belong to *Cercopithecus;* and it is also apparent that in the relative length of the molars they do not agree with any species of *Semnopithecus*, but that they do agree with *Macacus rhesus;* the evidence then so far is, that the fossils belong to the latter genus.

Now, with regard to the form of the teeth: in *Semnopithecus* and *Macacus*, the two first upper molars appear to me to be absolutely indistinguishable in the two genera: the last molar of *Macacus*, however, has the posterior talon-ridge forming a complete semicircle, which connects the two posterior cones of this tooth; in the corresponding tooth of *Semnopithecus*, on the other hand, this talon-ridge starts from the postero-internal cone, and curves upwards and outwards, to the base of the outer side of the crown, its curve forming only a quarter in place of half a circle, and not being connected with the outer cone at all. The last molars of the fossil specimens agree with the last molar of *Macacus* in this respect, and there seems, therefore, to be no doubt from this and the previous evidence that the specimens really belong to that genus.

Next, with regard to the question of species: the teeth are smaller than those of *M. silenus*, *M. rhesus*, and *M. radiatus*, and judging from the relative size of *M. radiatus* and *M. pelops*, the teeth of the latter would also be larger than those of the present specimens; again, in *M. rhesus* and in all other living species of the genus which I have seen, the anterior root of the zygoma is placed always behind the interval between the first and second molars, whereas in the fossil specimens, this root is exactly over this interval.

I have not been able to compare the fossil specimens with the teeth of other living species of *Macacus;* but as the former differ from the Indian species of the genus, and as all known Siwalik species of Mammals are extinct, the presumption is that the present specimens also belong to an extinct species.

Turning now to the fossil species of *Macacus*, we find that the following have been described; the small lower jaws described by Falconer from the Siwaliks and referred to above; a lower jaw from the London clay described by Professor Owen under the name of *Macacus eocenus*;[1] a portion of an upper jaw from the newer pliocene of Grays described by Professor Owen as *M. pliocenus*;[2] and a lower jaw from the pliocene of Montpellier described by Professor Gervais under the name of *M. priscus*.[3]

The small lower jaws from the Siwaliks described by Falconer belonged to an animal larger than *M. rhesus*, while Mr. Theobald's specimens belonged to an animal smaller than *M. rhesus;* now, since Falconer obtained two specimens of the lower jaw which agreed exactly in size, and since Mr. Theobald has also obtained two specimens of the smaller upper jaw, which also agree exactly in size, it seems to be probable that the latter belong to a different species from the former. The jaw on which *Macacus eocenus* of Owen was founded has been subsequently referred to *Hyracotherium*.[4]

Both *M. pliocenus* and *M. priscus* are too large to have belonged to so small an animal as that to which Mr. Theobald's specimens belonged.

It is therefore clear that the latter teeth do not belong to any named fossil species, and there is every probability that they do not belong to any living species: this being so, I shall propose to call the species *M. sivalensis*.

PROBOSCIDIA.

Genus: MASTODON.

I have already said in the Introduction that an adolescent cranium of the new Siwalik Trilophodont *Mastodon*[5] has been found in the Potwar; this cranium contains the two last upper milk-molars and the first true molar; a detached second upper true molar of the same species has also been obtained from the Siwaliks; and several detached teeth from Sind. These specimens appear to prove the specific distinctness of *Mastodon falconeri*.

[1] Brit. Foss. Mam. and Birds, p. 1.
[2] Sup. cit. Int., p. xlvi.
[3] Zoologie et Paléontologie Françaises, p. 11.
[4] Nicholson's Palaeontology, p. 466.
[5] Rec. Geol. Surv. India, Vol. X, p. 83.

Mastodon perimensis, Falc.

This species of Indian *Mastodon* has hitherto only been known from the mammaliferous beds of Perim Island in the Gulf of Cambay.[1] Among the specimens of *Mastodon* teeth in Mr. Theobald's Siwalik collection from the Punjáb there is one complete lower jaw, and several detached molars which must be referred to this species and which prove its range into that region. The molars of *M. perimensis* are at once distinguished from those of *M. latidens* by the transverse valleys being greatly blocked by tubercles, by the ridges being higher, and by there being a slight alternation in the arrangement of the inner and outer columns of the latter. The same teeth are distinguished from those of *M. sivalensis* by the number of ridges being less, and by the ridges being less alternately disposed, and the valleys being in consequence more nearly transverse. Among Mr. Theobald's specimens are a first and a second upper true molar which are more complete than any specimens represented in the "Fauna Antiqua Sivalensis;" of one of these specimens I shall hope to give a figure on a future occasion.

Some fragmentary *Mastodon* molars from Sind collected by Mr. Blanford, belong, I think, to this species.

The lower jaw belonged to a completely adult animal, and contains the two ultimate molars; the first of these teeth is imperfect; the second is, however, complete, and contains five transverse ridges and a talon, according to the normal tetralophodont formula.

This jaw agrees with the lower jaws of other Mastodons and differs from those of elephants, in that the summit of the coronoid process extends upwards as high as the condyle; the coronoid and condyle are, however, more closely approximated than in other species of the genus. The inferior and posterior borders of the jaw are nearly at right angles to each other, the angle being rounded off.

The symphysis of the mandible is produced into an elongated spout, extending more than a foot in advance of the first molar; the symphysis is three inches longer than the last molar. This specimen does not exhibit any traces of incisors; but another specimen of the symphysis of the same species, also collected by Mr. Theobald, shews a small cavity on the left side of the extremity, which is quite likely to be a semi-obliterated dental alveolus. It is therefore quite possible that this species with a spatulate mandible may have been furnished with incisors, which were shed before the animal became adult. If this be so, the species would agree in character with the European *Mastodon longirostris*, which also has a spatulate mandible and lower incisors.

The most important measurements of this specimen are as follows:—

Length from hinder border of last molar to distal extremity of symphysis .	29·0
„ „ anterior border of penultimate molar to „ „ .	18·5
„ of last molar	10·7
Interval between condyle and coronoid process	5·0

Mastodon latidens.

In this species, I have lately discovered that the last milk-molar of the upper jaw was displaced vertically by a simpler premolar, which was not previously

[1] Falconer's Palæontological Memoirs, Vol. II, p. 15.

known to have been the case. The specimen from which this interesting discovery was made consists of a portion of a left maxilla containing a single tooth in use which carries four ridges and which measures $3\frac{3}{4}$ inches in length. Above the base of this tooth the broken jaw shews a complete germ of a premolar, which I have removed from its matrix: the germ is oval in shape, and carries only two ridges, and fore-and-aft talons. Since the larger tooth is situated below a premolar, it is clear that the former is a milk-molar, and since it carries four ridges, that it is the last or third tooth of that series. I cannot, of course, say whether the penultimate milk-molar of *M. latidens* was succeeded by a premolar, but not unprobably such was also the case.

Genus: STEGODON.

Stegodon cliftii.

This species was originally named upon the evidence of teeth obtained solely from Ava and Burma, and I cannot find more than one recorded instance of its having been obtained beyond those countries. This instance occurs in the catalogue of the fossil vertebrata of the Asiatic Society of Bengal,[1] where a portion of a mandible of *S. cliftii* (No. $\frac{S}{64^2}$) is stated to have been obtained from the Siwaliks. In the table of the species of *Mastodon* and Elephant given on page 14 of the second volume of the "Palæontological Memoirs," the distribution of this species, like that of *Mastodon latidens*, is given as "Southern India and Ava;" now, the latter species is well known as occurring in the Siwaliks, and "Southern India" may be a misprint for Siwaliks; on the other hand, Southern India is given as the locality of *M. pandionis* which was obtained from the Deccan, and it is possible that *M. latidens* and *S. cliftii* have also been obtained from the Deccan: if so, however, all record of this has been lost; on this supposition the word "Siwaliks" is omitted from the distribution of *M. latidens*. All the specimens of *S. cliftii* figured in the "Fauna Antiqua Sivalensis" of which the locality is given, were obtained from Ava and Burma, and therefore the only recorded instance of the species occurring in the Siwaliks is the above-mentioned lower jaw.

The distribution of this species being so uncertain, it is a matter of some interest that I am now able to state clearly that the species does occur in the Siwaliks. I am not aware that any specimens of *Stegodon cliftii* have hitherto been recorded as having been found in the Sub-Himalayan Siwaliks.

Two specimens of molars of a *Stegodon* sent by Mr. Theobald seem undoubtedly to belong to this species: the first specimen is a portion of the (probably) first upper true molar; it carries five complete transverse ridges, a sixth having been broken away. In the number of ridges the tooth agrees with the first molar of *S. cliftii;* it differs from the corresponding tooth of *S. insignis* by having six, in place of seven ridges, and by being wider; and by the more open valleys: it is also much wider, and the valleys are more open than in the tooth which I refer below to *S. bombifrons*, though that tooth also contains six ridges. The second specimen is a right ramus of the mandible containing the ultimate true molar: this tooth agrees in general character with the corresponding tooth of *S. cliftii* represented

[1] Palæontological Memoirs, Vol. I, p. 113.—Cat. Foss. Vert. Mus. A. S. B., p. 75.

in fig. 5, Plate XXX, of the "Fauna Antiqua Sivalensis;" the latter, however, carries eight, in place of seven ridges, the number of ridges frequently varying by one or more in this tooth. The last lower molar of *S. insignis* carries from 11 to 13 ridges, and that of *S. bombifrons* 9 ridges; the latter tooth is further distinguished from the last lower molar of *S. cliftii* by carrying a large number of cusps on the ridges, whereas there are only four or five on the last lower molar of *S. cliftii*. The ridge formula of the true molars of *S. cliftii* will therefore now be as follows:—

$$\frac{6+6+8}{6+6+(7-8)}$$

Stegodon bombifrons and S. sinensis.

A considerable number of molar teeth of other species of *Stegodon* have lately been collected by Mr. Theobald, among which there are some which call for a short notice here; most of these teeth belong to the "intermediate molars." It may be well to state here that the whole of the ridge formula of the molars of *S. insignis* has been determined by Dr. Falconer ("Palæontological Memoirs," Vol. II, p. 86) and is as follows:—

$$\overset{\text{Milk-molars.}}{\frac{2+(5-6)+7}{2+5+7}} \qquad \overset{\text{Molars.}}{\frac{7+8+(10-11)}{7+(8-9)+(11-13)}}$$[1]

The ridge formula of *S. ganesa* is considered by Falconer to be the same: the whole ridge-formula of *S. bombifrons* is not known, but it will be gathered from the figures in the F. A. S. that it is lower than in *S. insignis;* the third milk-molar has six ridges. (F. A. S., Pl. XXIX A, fig. 1.) Of *Stegodon cliftii* the ridge-formula of the anterior teeth is not known; the two first true molars, however, carry each six ridges, and I have already given their formula.

Having premised this much, our comparisons will be the more easily made. The first among Mr. Theobald's specimens to which I wish to call attention is a portion of a maxilla, containing the last milk-molar, and the first true molar, the latter tooth I shall often refer to as *a*; the former tooth appears to have carried six ridges, but is much worn; the latter carries six ridges, and fore-and-aft talons, the former joining the first true ridge in the middle; there is a slight tendency to a median division in the ridges, especially the anterior ones; each ridge carries fourteen or fifteen tubercles, and the four last ridges are much curved. The dimension of these teeth are as follows:—

Length of third milk-molar	4·1
Width of " "	2·3
Length of first true molar	5·9
Width of " "	3 0
Interval between 3rd and 4th ridges of first true molar . .	1·0

Now, it is quite clear, from the number of ridges carried by the first true molar, that these teeth cannot belong to *S. insignis* or *S. ganesa;* the first molar agrees with the homologous tooth of *S. cliftii* in carrying side ridges, but differs in form

[1] The ridges of milk-molar 2 are given as 5, in the specimen represented in F. A. S., Pl. XIX., fig. 1.

and relative size. The dimensions of the first upper true molar of *S. cliftii* represented in figure 2 of Plate XXX of the F. A. S. are as follows:

Length	6·1
Width	3·3
Interval between 3rd and 4th ridges	1·2

The new tooth is, therefore, relatively narrower, and is further distinguished by having a large hind talon which is wanting in *S. cliftii.* Of Falconer's species of *Stegodon* there therefore only remains S. *bombifrons* to which our specimens can belong; as the third molar of this species has six ridges, the first true molar should also have six ridges, and at first I thought of referring the teeth under discussion to *S. bombifrons* had it not been for certain reasons to be immediately noticed.

The true molar in this jaw agrees with the second milk-molar of a *Stegodon* from China, referred by Professor Owen[1] to a new species under the name of *S. sinensis,* in the following characters; both these teeth have curved transverse ridges, which carry from fourteen to fifteen tubercles, and have a slight median division of the ridges. In both teeth there is an imperfect ridge at the anterior end, which joins the middle of the first complete ridge: this imperfect ridge I consider to be only a talon, though Professor Owen regards it as the first true ridge. From a comparison of the Chinese and Siwalik specimens, I have not the slightest doubt but that they belong to the same species; the length of the Chinese second milk-molar is 2·9 inches and its width 2·0 inches: dimensions which would well correspond to those of the tooth which should precede the third milk-molar in the Siwalik specimen.

We have now to consider another first upper molar of a *Stegodon* from the Punjáb which I will designate as *b;* this tooth carries only six ridges, and cannot therefore belong to *S. insignis* or *S. ganesa.* These ridges are very closely approximated and run straight across the tooth; there is a large hind talon. The length of this tooth is 4·9 inches, its width 2·9 inches, and the distance between the third and fourth ridges 0·8 inch. From these dimensions it will be quite apparent that this tooth is not the first true molar of *S. cliftii,* nor of the Chinese species. It at one time occurred to me that this tooth might be the third milk-molar of *S. cliftii,* but the approximation of the ridges is against that view. Again, the length of the worn third milk-molar of that species represented in figure 1 of Plate XXX of the F. A. S. is only 3·3 inches and its width 2 inches; it is therefore clear that tooth *b* does not belong to *S. cliftii.*

Now, with regard to *S. bombifrons,* tooth *b* agrees with the hinder molars of that species, in having broad and blunt ridges, ("Palæontological Memoirs," Vol. I, p. 81,) in having a hind talon, and having fewer ridges than the first molar of *S. insignis.* There is, therefore, every presumption of this tooth being the first true molar of *S. bombifrons.*

This being so, the first molar *a* and the Chinese tooth cannot belong to *S. bombifrons,* and since they do not belong to any other of Falconer's Siwalik species, we must retain for these Owen's name of *S. sinensis.*

[1] Quar. Journ. Geol. Soc. Lond., Vol. XXVI. p. 417, pl. 27.

One other tooth remains to be mentioned : this specimen is a small upper molar of a *Stegodon*, which from its carrying four ridges only, and from its size, must be a second milk-molar; the length of this tooth is 2·2 inches, and its width 1·4 inch. It cannot belong to *S. insignis* and *S. ganesa*, since the second milk-molar of those species has five or six ridges (F. A. S., Plate XIX, fig. 1); neither can it belong to *S. sinensis*, since it is much smaller than the homologous tooth of that species figured by Professor Owen, and differs from that specimen in having no anterior talon, and in having straight ridges.

It may belong to *S. cliftii* or *S. bombifrons;* if it belong to the former, it conclusively proves that tooth *b* cannot be the third milk-molar of that species, as the latter would be far too large to have immediately followed it. If this second milk-molar belong to S. *bombifrons*, as I think probable, it most conclusively proves that the homologous Chinese tooth cannot belong to that species.

The inference from the above would be that there existed a fifth species of *Stegodon* in the Siwaliks, which is the same as *S. sinensis* of Owen; and also that both that species and S. *bombifrons* had a low ridge formula, which shews that they are closely connected with the Mastodons and *S. cliftii.* Professor Owen at page 420 of his notice of the Chinese *Stegodon* suggests that the two imperfect hinder molars, represented in figures 5 and 6 of Plate XXIX A of the F. A. S., which were considered latterly by Falconer to differ from the named species, belong also to *S. sinensis.* The discovery of a tooth in the Siwaliks, which corresponds with the Chinese specimen of that species, confirms that suggestion; I shall hope on a subsequent occasion to be able to present fuller details of the dentition of *S. bombifrons* and *S. sinensis.*

Genus: DINOTHERIUM.

Of this genus Mr. Blanford has obtained from Sind a very beautiful specimen of a ramus of the mandible, containing the four last teeth in perfect preservation; several detached teeth have also been obtained from Sind, as well as a single milk-molar from Kúshalghar. All the specimens seem to belong to *D. pentapotamiæ;* the small size of the new specimen of the mandible quite confirms the distinctness of the latter species from *D. indicum.*

With the addition of the above-mentioned species, two of which are new to the Sub-Himalayan Siwaliks, the Proboscidian Fauna of the Siwaliks of the Western Punjáb is the largest yet known in any one area; it comprehends the following species, all of which are represented in the collection of the Indian Museum :—

Dinotherium pentapotamiæ, nobis.
Mastodon (Trilophodon) falconeri, nobis.
Mastodon (Tetralophodon) latidens, Clift.
Mastodon (Tetralophodon) perimensis, Falconer.
Mastodon (Pentalophodon) sivalensis, Falconer.
Stegodon cliftii, Falconer.
Stegodon bombifrons, Falconer.
Stegodon sinensis, Owen.

Stegodon insignis, Falconer
Loxodon planifrons, Falconer.
Euelephas hysudricus, Falconer.

Stegodon ganesa may also not improbably occur in the Western Punjáb, but the teeth are undistinguishable from those of *S. insignis*, and no cranium has been found.

The distribution of the Indian fossil Proboscidia, as far as I can at present determine it, seems to be as follows:—

DISTRIBUTION OF INDIAN FOSSIL PROBOSCIDIA.

[The abbreviations of localities used in the table are as follows: B, Burmah. D., Siwaliks of Dehra Dun District. De, Deccan. C, China J, Jamna Valley. K. Kach. N. Nerbudda Valley. P., Western Punjab P. I., Perim Island S, Sind. The following refer to books: A. S. B., Falconer's "Catalogue of Fossil Vertebrata in Asiatic Society of Bengal." F. A. S., "Fauna Antiqua Sivalensis" P. M., "Palæontological Memoirs." R. G. S. I., "Records of Geological Survey of India."]

Dinotherium indicum, P. I.[1]
Dinotherium pentapotamiæ, K.; P.; S.
Mastodon (Trilophodon) falconeri, P.; S.
Mastodon (Trilophodon) pandionis, De.[2]
Mastodon (Tetralophodon) latidens, B.[3]; D.; P.; P. I.[4]; S.[5]
Mastodon (Tetralophodon) perimensis, P.; P. I.; S. (?).
Mastodon (Pentalophodon) sivalensis, D.; P. I.
Stegodon cliftii, B.; P.
Stegodon bombifrons, D.; P.
Stegodon sinensis C.; D. (?); P.
Stegodon insignis, D.; P.; N[6]
Stegodon ganesa, D.; N.[7]
Loxodon planifrons, D.; P.
Euelephas hysudricus, D.; P.
Euelephas namadicus,[8] N.; J.

In the table of Proboscidia given on page 14 of the "Palæontological Memoirs" certain species, such as *M. latidens* and *S. cliftii*, are mentioned as occurring in "Southern India," and not in the Siwaliks; this question has already been sufficiently discussed above.

[1] F. A S., pl. 3.
[2] Pal. Mem., Vol. II, p 15.
[3] A. S. B., p. 11.
[4] A. S. B., p. 206.
[5] A. S. B., p. 256.
[6] A. S. B, p. 316.
[7] R. G. S. I., X. p. 31.

[8] I am informed that during the past year Professor Leith-Adams, in the publications of the "Palæontographical Society," has endeavoured to prove the identity of the Nerbudda Elephant with *E. antiquus* of the pliocene of Europe. I have not at present seen the Memoir in question, and therefore cannot discuss the question fully. I may, however, observe that Dr. Falconer, who named the two species, considered them as distinct, but closely allied (Pal. Mem., Vol. II, p. 108); of the Indian species Dr. Falconer remarks (*sup. cit.*, p. 642): "It (*Elephas namadicus*) belongs to the same group, *Euelephas*, as the existing Indian Elephant, but it is broadly distinguished from that species and from all other known species by a very marked peculiarity in the form of the cranium, in addition to dental and other characters."

ARTIODACTYLA

SUINA.

Genus: HYOTHERIUM.

A considerable number of detached molars of both bunodont and selenodont pig-like animals have been obtained by Messrs. Blanford and Fedden from Sind; to some of these specimens I have already referred at pages 76 and 225 of the tenth volume of this publication.

At page 76 of that volume I shortly described certain upper molar teeth which I then referred to *Sanitherium schlagintweitii*, thinking that they agreed in size with the lower molars of that species, and that from their form they could not belong to any European genus; I, however, pointed out their resemblance to the molars of *Hyotherium* (or *Chœrotherium*, as it is often called).

I now find that these teeth do really belong to *Hyotherium;* the first specimens were distorted and crushed, and consequently were altered from their true form; those specimens, moreover, were unusually small, and were both first molars: the last molars, which have now been obtained, shew that they are too large to have belonged to *S. schlagintweitii.*

Some of the smaller of these upper molars are almost identical in form with certain teeth of *H. medium* from the upper miocene of Weissenau, in the collection of the Indian Museum; they are, however, of larger size, and are therefore probably distinct; if such be the case, I shall propose to call the Sind form *H. sindiense.*

It will be inferred from the above that the upper molars of *Sanitherium* are still unknown; the name of that genus must also be removed from the list of the tertiary Mammalia of Sind.

ANTHRACOTHERIUM, RHAGATHERIUM, AND CHŒROMERYX.

The confusion caused by the reference of teeth of two distinct genera to *Chœromeryx (Anthracotherium) silistrensis*, has been so great, that it is somewhat difficult to recover from it. It will be remembered that at page 225 of the tenth volume of the "Records" I separated the five-columned tooth, which had been referred to the above species, from the four-columned teeth which really belong to *C. silistrensis;* and that, at the same time, I considered that the former might possibly belong to *Rhagatherium*, though I was not certain of this (owing to the fact that we have scarcely any specimens of European genera of extinct pig-like animals in the Indian Museum for comparison). It has subsequently occurred to me that there is really no reason, as far as I can gather from their form, for separating the five-columned teeth in question from the genus *Anthracotherium*, although they resemble in some points those of the closely allied *Rhagatherium;* and that consequently Pentland was really right in assigning the five-columned tooth from Sylhet to *Anthracotherium*, but that he was wrong in assigning also the four-columned teeth to the same genus and species; subsequent authors, as I have said in my former notice, erred in referring the five-columned tooth to *Chœromeryx*, which genus was made expressly for the four-columned teeth.

Considering, then, that there is really no reason for separating the five-columned teeth from Sind and Sylhet from the genus *Anthracotherium*, it will occur to the reader that at page 78 of the tenth volume of the "Records" I described under the name of *Anthracotherium punjabiense* a lower jaw of a species of that genus obtained from the Siwaliks of the Punjab, and that I then remarked, "although these teeth belong to an animal of about the same size as *Chœromeryx*, they cannot be referred to that genus, as they present no generic points of difference from the teeth of the European species of *Anthracotherium*." Now, since we have found that the upper five-columned teeth falsely referred to *Chœromeryx* really do belong to *Anthracotherium*, it will be pretty evident that as they agree in size with the lower molars assigned to *A. punjabiense* that they really belonged to the same species.

Now, with regard to the specific names, it is pretty evident that Pentland, in giving the name of *Anthracotherium silistrense* to the Sylhet teeth, relied upon the larger five-columned tooth, neglecting the distinct characters of the smaller four-columned teeth. It is also tolerably evident that Pomel, in making the new genus *Chœromeryx*, founded it on the evidence of the four-columned teeth, the original figure[1] of the five-columned tooth being indistinct, though a second figure given in the "Fauna Antiqua Sivalensis,"[2] and apparently copied from the original, is distinct.

I therefore think that the name *Anthracotherium silistrense* must apply to the five-columned teeth from Sind and Sylhet and also to the lower jaw from the Punjab, and that consequently my two specific names of *sindiense* and *punjabiense* must be abandoned.

With regard to the specific name of *Chœromeryx*, I cannot find in the original notices that the specific name of *silistrensis* is coupled with this genus; but since *Chœromeryx* is quoted as being equivalent to *Anthracotherium silistrense*, it appears evident that the specific name was intended to apply to that genus, though that genus has really no right to it. One would therefore be at liberty to assign a new name to *Chœromeryx*, but I think it best to continue to apply the name of *silistrensis* to the species, irrespective of the question of the identity of the genus with *Merycopotamus*.

The synonomy of *Anthracotherium silistrense* and *Chœromeryx silistrensis* will therefore stand as follows:—

ANTHRACOTHERIUM SILISTRENSE—Pent. (excluding four-columned teeth).
Syn. *Anthracotherium punjabiense*, Lyd.
Rhagatherium (?) sindiense, Lyd.
Chœromeryx, Pomel, in parte.

CHŒROMERYX SILISTRENSIS, Pomel (excluding five-columned tooth).
Syn. *Anthracotherium silistrensis*, Pent., in parte.

I regret the part which I have taken in adding to this confusion of names; but under the circumstances it was almost unavoidable until I discovered the original errors in identification.

[1] Trans. Geol. Soc. Lond., Ser. II, Vol. II, pl. 45, figs. 4, 5. [2] Pl. 68, fig. 23.

Both the upper and lower teeth of *Anthracotherium silistrense* are exceedingly like, both in size and form, to the teeth of an *Anthracotherium* from the brown-coal of Bonn (oligocene), described by Dr. Boettger under the name of *A. breviceps* (Troschel, sp.);[1] the lower molars of the Indian and European forms are identical in size, while the Indian upper molar is rather larger than the European. If the two forms belong to one species (which I cannot decide without comparing the specimens together), the specific name of *silistrense* would stand, since this name was published by Pentland in 1829, while the specific name of *breviceps* was given by Troschel in 1849.[2]

Irrespective of the, at all events, closely allied European form, *Anthracotherium silistrense* had a very wide range in India, having been found in Sylhet, in the Punjáb, and in Sind. I have already referred to the possibility of the lower jaw of this species from the Punjáb having been derived from a zone below that which produces the great majority of mammalian fossils; the occurrence of the genus in the Sind Siwaliks agrees well with the general older types of mammalian genera which occur in that area; among these older genera, we may specially mention *Hyopotamus* and *Hyotherium*, which in India have not hitherto been found beyond the Sind area, and which in Europe did not survive, as far as we yet know, beyond the lower miocene period.

MERYCOPOTAMUS-LIKE ANIMALS.

It will perhaps be remembered that at page 78 of the previous volume of the "Records" I briefly noticed a single upper molar tooth of an extinct Siwalik animal allied to *Merycopotamus*, and which I thought belonged to a new genus. During the past season Mr. Blanford has obtained from the Siwaliks of Sind two more imperfect upper molars of the same species, and in addition a penultimate lower molar of an animal of this class, which in size agrees well with the upper molars, and which does not belong either to *Merycopotamus* or *Hyopotamus*; I think it is, therefore, extremely probable that this lower molar belonged to the same animal as the above-mentioned upper molars. The lower molar is distinguished from the corresponding tooth of *Merycopotamus* by having a lower crown, by the transverse valley being nearly blocked instead of freely open on the inner side, by the worn dentine surfaces of the inner and outer columns being of nearly equal width, and by the dentine surface of the inner column being equal to the whole length of that column, instead of occupying its summit only as in *Merycopotamus*. The form of the same dentine surfaces also distinguishes this tooth from that of *Hyopotamus*, in which, as is well shewn in Professor Owen's figure on plate viii of the fourth volume of the "Quarterly Journal of the Geological Society," the dentine surface of the outer column is large and wide, while that of the inner column only occupies the summit of the column, and not its whole length; the inner column of the new tooth is flatter and less conical than in either *Hyopotamus* or *Merycopotamus*.

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[1] Dunker and Zittel's Palaeontographica, Vol. XXIV, p. 163.
[2] Boettger, *sup. cit.*

The entire distinctness of these upper and lower molars from those of any known genus confirm the conclusions previously arrived at as to the distinctness of the genus to which they belong. I propose to call the new genus *Hemimeryx*.

Besides the above-mentioned specimens, Messrs. Blanford and Fedden have also collected from the same formation several detached upper molar teeth, which belong to two other species of *Merycopotamoids*, apparently generically distinct from any of the above, or from *Chœromeryx*. Both these types of teeth are of small size, the one is considerably larger than the other; they belonged to animals intermediate between the bunodont and selenodont suina; both types carry four cones only on the masticating surface; one lower molar, probably belonging to the same species as the larger upper molars, has also been obtained. Mr. Fedden has also obtained from Sind the hinder half of a cranium of a *Merycopotamoid*, which, I think, may probably have belonged to the same species as the larger of the molars in question. Should further researches prove, as I think will be the case, the generic distinctness of these teeth, I shall propose the name of *Sivameryx* for the new genus. All the above specimens will be subsequently figured.

Of the Sind *Hyopotamus*[1] the Indian Museum has received two imperfect specimens of the last lower molar: these teeth agree very closely in character with the European *H. bovinus;* we have also received a portion of a lower jaw containing sections of the bases of the two last lower molars, which agree in form and size with the last-mentioned lower molars. The fragment agrees very closely with the corresponding portion of the lower jaw of *H. bovinus* figured in the above-mentioned paper of Professor Owen's. The depth of the Sind jaw is 1·3 inch, and the length of the section of the last molar 1·32 inch; these dimensions seem to be identical with those of *H bovinus;* the upper molars of the Sind species are, however, less concave on the external (dorsal) surfaces of the outer columns than those of the European species.

From the perusal of this and other papers by myself on the same subject, it will be gathered that the Sind Siwaliks afford us evidence of the former existence in that area of a very large assemblage of both bunodont and selenodont pig-like animals; a group which is very sparingly represented in the typical Siwaliks, and of which *Merycopotamus* seem to have been the last representative, the group having now entirely disappeared from the living faunas of the globe.

We cannot help having a feeling of regret that these interesting animals are at present only known to us from the evidence of isolated teeth or of a few fragmentary crania and bones. The separation of the upper and lower teeth which generally happens in Siwalik fossils often renders it a matter of extreme difficulty to refer the upper and lower molars to their respective owners, as is exemplified in the case of the above-mentioned teeth of *Hyotherium* and *Anthracotherium*.

I am not sure whether *Merycopotamus* occurs in Sind or not, as the bones which I at first thought belonged to that genus which have been obtained by Messrs. Blanford and Fedden may very probably belong to some of the allied

[1] Rec. Geol. Surv. India, Vol. X, p. 77.

genera. There are no unworn molars from Sind which I can refer to *Merycopotamus*, but it is just possible that certain much-worn molars may really belong to it.

Genus: Sus.

Of this genus two species, *S. giganteus* and *S. hysudricus*, have already been named from the Siwaliks; another species *(Sus pusillus)* was made by Dr. Falconer from the lower jaw of *Sanitherium schlagintweitii*. Among Mr. Theobald's Siwalik collection from the Punjáb there are two fragments of mandibles of a species of *Sus* which are so small that they cannot possibly have belonged to *Sus hysudricus*, which is the smallest of the named species. The most perfect of the two specimens is a part of the left ramus of the mandible containing the three true molars of the permanent dentition, which prove that the specimen belonged to a fully adult animal. The teeth of the species of the genus *Sus* are so like one another in form that it is generally impossible to tell one species from another by the teeth alone: except in the matter of size I cannot distinguish between the teeth of the small specimen and those of *S. hysudricus*, though the accessory tubercles in the outer valleys of the last molar seem to be somewhat larger in the former. The discrepancy in the size of the present specimen and of the jaw of *S. hysudricus* is, however, so great, that on this evidence alone I have referred the two specimens in question to a new species, for which I propose the name of *S. punjabiensis*; the species is, I believe, the smallest of the genus. Below I have given the dimensions of the specimen, and have added for comparison the corresponding dimensions of the smallest specimen of the lower jaw of *S. hysudricus* which is contained in the collection of the Indian Museum:—

	S. punjabiensis.	*S. hysudricus.*
Length of three true molars	1·46	2·35
„ of last molar	0·61	1·19
Width of „ „	0·38	0·65
Length of penultimate molar	0·49	0·70
Width of „ „	0·35	0·55
Length of first molar	0·32	0·50
Width of „ „	0·29	0·45
Depth of jaw at last molar	0·69	1·70

Sus giganteus, Falc.

From the red and gray Siwalik sandstones of Niki in the Punjáb, Mr. Theobald has sent a very magnificent cranium of this species, which is the largest and most perfect yet obtained. The lower jaw is attached to the cranium, and the whole of the dental series is complete; in fact, the only noticeable damage that the specimen has received is a certain amount of lateral squeezing.

This cranium was obtained from the deposit which I have already referred to, in which were buried such a vast number of bones in a small area; to the left side of the cranium of the pig was attached a cranium of a young *Mastodon*, which was necessarily somewhat damaged in the extraction of the former, while between the rami of the mandible was firmly fixed the head of a large Ungulate

humerus, and other bones were in close proximity. I merely mention these facts to shew the number of specimens buried in this one place.

The cranium, except in the matter of its vastly superior size, seems scarcely to differ from that of the living Indian pig; the profile of the fossil is, however, rather more concave. The following are the chief dimensions of the specimen:—

	Inches.
Length from supra-occipital to incisors	23·00
Interval between supra-occipital and angle of mandible	8·00
Width above orbits	5·40
Length of molar series	6·30
„ of exposed portion of lower canine	2·50
„ „ „ „ incisors	1·40
Diameter of upper canine	1·25
Depth of mandible at last molar	3·80
Width of symphysis of mandible	2·60

In addition to the cranium, Mr. Theobald has also sent down the two median metacarpals of the left foot of a gigantic *Sus*, which doubtless belong to the same species, and very probably, since they are from the same locality, to the same individual; they do not differ, except in size, from the metacarpals of the living pig. I give their dimensions in order that they may be compared with those of the latter; in the second column are given the dimensions of an outer metacarpal of the smaller Siwalik *Sus hysudricus*:—

	S. gigant.	*S. hysud*
Length of outer metacarpal	4·50	3·10
Width of distal extremity of outer metacarpal	1·18	0·67
„ of proximal „ „ „	1·50	0·85
Length of inner metacarpal	4·40	

These bones are about the size of the metacarpals of the living Malay Tapir, and indicate that the extinct Indian pig, must have about equalled in size the former animal.

Genus: HIPPOHYUS.

This genus, which is confined to the Siwaliks, seems to have been hitherto known only by the cranium and fragments of the mandible, figured on plates 70 and 71 of the "Fauna Antiqua Sivalensis." Mr. Theobald has collected near Asnot a considerable number of specimens of the cranium and mandible of this genus, and one or two specimens had been obtained from the Punjáb in previous seasons; the great number of specimens obtained from Asnot illustrates the very local distribution of many of the Siwalik mammals. Of the specimens of crania and upper molars recently obtained, some are slightly larger and others slightly smaller than Falconer's figured specimen, but I can see no evidence of specific distinction, the gradation from one to another being so regular.

In the mandibles, however, there is such a difference in the size and proportion of the molars that I cannot but think that there is evidence of a second species smaller than *H. sivalensis*. Below I have compared together the

dimensions of a mandible of *H. sivalensis (a)*, and one of the smaller specimens *(b)* —

	a.	*b.*
Length of three true molars	3·02	2·30
,, of first molar	0·55	0·45
Width of ,, ...	0·52	0·40
Length of second ,, ...	0·80	0·70
Width of ,, ,, ...	0·75	0·48
Length of third ,, ...	1·71	1·20
Width of ,, ,, ...	0·80	0·55

It will be seen from the above measurements of the teeth of the two jaws that those of the smaller jaw are proportionally narrower than those of the larger.

RUMINANTIA.

CAMELOPARDALIS AND HYDASPITHERIUM.[1]

Among the large collection of specimens obtained by Mr. Theobald, during his last season's work in the Siwaliks, there occur a considerable number of both upper and lower teeth of various species of Giraffe-like animals, some of which belong to new species, and possibly to new genera, while others illustrate more completely the dentition and affinities of previously known species.

A certain amount of difficulty occurs in referring all these specimens to their respective species, since it is in several cases not easy to say whether certain lower molars should be referred to the same species as certain upper molars: or, again, whether certain lower molars which cannot be referred to the same species as any of the upper molars, should be referred to the same or to a different genus. It will therefore be understood that in regard to the lower molars, some of the determinations are only provisional.

The discoveries of new Giraffoid animals in the Sub-Himalayan Siwaliks are gradually bringing to light a group of animals of whose existence scarcely anything is known in other parts of the world. At the present time there exists of this group only the one Giraffe of Africa, which stands out alone and isolated from all other living Ruminants, and is evidently the last specialized survivor of a lost group. In the miocene of Attica and in the Siwaliks fossil species of this genus occur; and in the former deposits there also occur the remains of the *Helladotherium*, which is the only other European member of the group.

In Asia, we now know of the former existence of at least four genera, namely, *Sivatherium*, *Bramatherium*, *Hydaspitherium*, and *Vishnutherium*. Of the third of these genera we now know of the existence of three species (unless one belongs to a new genus), one of which is intermediate in the form of the mandible between the *Sivatherium* on the one hand, and the Giraffe on the other.

It is, of course, much to be regretted that some of the species to be noticed here are only known by fragments of their jaws and teeth, so that we can only

[1] Originally wrongly named *Hydaspidotherium.*

guess vaguely and darkly at the true affinities of their owners; even, however, the bare knowledge of the existence of such highly interesting forms of older mammalian life, has a great importance in all schemes for the classification and evolution of the most specialized class of Vertebrates.

Many of the specimens noticed in the present paper will not require further illustration, and they are therefore described at some length; others, again, will require figuring and more minute description on a future occasion, and are therefore only shortly noticed in the present paper.

Commencing with the genus *Camelopardalis*, we may notice that but few molars have hitherto been found, and that consequently the present specimens considerably enrich our knowledge of the Indian fossil species. In the true upper molars I have only found evidence of one species, namely, *C. sivalensis;* certain lower molars and premolars, however, seem to indicate the former existence of a second larger species, and of a third smaller species.

The specimens collected by Mr. Theobald are the following: a portion of a left maxilla containing the three molars; a portion of a right maxilla, which seems to have belonged to the same individual, and contains the two last premolars and the two first molars; the two last upper molars of the right side; two detached penultimate upper molars; two detached upper first molars; a single last upper premolar of the right side; a portion of a right maxilla containing the two last milk-molars and the first permanent molar; a fragment of a left ramus of the mandible containing the two last permanent molars; another fragment containing the last tooth of the opposite side, from beds low in the series; a first right lower molar; a last right lower premolar of large size; a penultimate left lower premolar; the two anterior premolars in a fragment of the right ramus of the mandible belonging to a larger species: and the last lower milk-molar of the left side.

The teeth of the fossil Siwalik Giraffe hitherto figured and described are the two last upper molars, the penultimate upper premolar, the three lower molars, and the last lower premolar; all the above specimens were obtained by Dr. Falconer and are figured on plate 16 of the "Palæontological Memoirs." In addition to the above, a fragment of a mandible with the last premolar and two first molars, obtained by Mr. Theobald from the Punjáb, has been figured by myself in the "Palæontologia Indica." [1]

In the present paper I shall notice the more important of the recently-discovered specimens, giving the dimensions of some of them. As the majority of these specimens do not differ in character from the corresponding teeth of the living Giraffe, they do not require minute description, nor will it be necessary to give figures of them.

The two most perfect specimens of the maxilla contain between them the five last teeth; of these I have appended the measurements, which are given in the first column (*a*) of the following table; in the second column (*b*) I have given

[1] Ser. X, Vol. I, 2, plate VII, fig. 15.

the measurements of the corresponding teeth obtained by Dr. Falconer and taken from page 202 of the first volume of the "Palæontological Memoirs;" while in the third column (c) I have given the measurements of the corresponding teeth of the living *C. giraffa*:—

	a.	*b.*	*c.*
	In.	In.	In.
Length of two last molars	2·40	2·50	2·55
" of last molar	1·27	1·20	1·21
Width of " "	1·25	1·40	1·30
Length of penultimate molar	1·19	...	1·21
Width of " "	1·35	1·45	1·35
Length of first molar	1·07	...	1·10
Width of " "	1·10	...	1·20
Length of last premolar	0·98	...	0·90
Width of " "	1·06	...	1·10
Length of penultimate premolar	0·80	1·00	1·08
Width of " "	0·98	1·12	1·22

It will be seen that the present teeth agree very closely in size with Falconer's specimens generally, being, however, slightly smaller. One very important difference distinguishes the dental series of the fossil species from that of the recent species: in the former the last premolar is both longer and broader than the penultimate premolar, while in the recent species the penultimate premolar is both longer and broader than the last premolar. In my above-quoted notice of the lower jaw of the fossil species, I pointed out that the jaw was much deeper than that of the recent species, and that the last premolar was relatively more elongated; and also that the one known cervical vertebra was shorter.

There are, therefore, many points of distinction between the recent and fossil forms, though the resemblance of the true molar series is very close in the two. At page 202 of the first volume of the "Palæontological Memoirs," Dr. Falconer remarks, that the penultimate upper premolar of the fossil species has three tubercles at the inside of the base, which do not occur in the corresponding tooth of the recent species; in Mr. Theobald's specimens these tubercles are likewise absent, and therefore do not seem to be of any specific value; indeed, this tooth appears to be liable to vary in the recent species, as in a specimen of a recent cranium in the Indian Museum, the penultimate upper molar is furnished with a distinct cingulum on the inner side, which is not noticed in Owen's "Odontography," or in Dr. Blainville's figures.

The other specimens of upper true molars collected by Mr. Theobald do not require further notice, as they are in no wise different from the preceding specimens. The specimen of the maxilla with the two last milk-molars has the first tooth somewhat injured; this tooth is narrower in front than behind, as is usually the case in Ruminants; the last milk-molar has a distinct tubercle in the valley separating the inner columns; in the permanent molars of *C. sivalensis* there is generally no trace of any similarly-placed tubercle, though some specimens in the Indian Museum and Falconer's original specimens shew a very small one; in the recent species there seems to be always a tubercle in the inner valley of

the upper molars. The dimensions of the specimen with the upper milk-molars are as follow:—

	Inches.
Length of first true molar	1·09
Width of " "	1·18
Length of last milk-molar	0·98
Width of " "	0·90
" of penultimate milk-molar	0·70

The portion of the left ramus of a mandible containing the two last molars, in respect of the last tooth agrees well with Falconer's original specimen of the same tooth; the penultimate molar is, however, somewhat smaller than the corresponding tooth of the lower jaw figured by me in the "Palæontologia Indica," which has already been referred to. Unfortunately the lower part of the mandible of the new specimen has been broken away, but from its thickness at the broken part it would appear that the jaw was deep, as in the figured specimen.

The next specimen, which contains the last molar of the right ramus of the mandible, has a narrower jaw, and therefore cannot have belonged to the same species as the abovementioned figured jaw; the tooth of the new specimen is also somewhat smaller than the corresponding tooth of Mr. Theobald's other specimen of the mandible.

In the following table I have given the dimensions of the figured jaw in the first column (*a*); in the second column (*b*) the dimensions of Falconer's specimen of the last molar; in the third column (*c*) Mr. Theobald's specimen with two molars; in the fourth column (*d*) the jaw of the living Giraffe; and in the fifth column (*e*) Mr. Theobald's specimen with the last molar only; I shall subsequently refer to the specimens under the heads of the above letters:—

	a.	*b.*	*c.*	*d.*	*e.*
Length of penultimate molar	1·25	...	1·10	1·15	...
Width of " "	1·00	...	0·90	0·90	...
Length of last molar	...	1·7	1·69	1·75	1·40
Width of " "	...	1·0	0·90	0·90	0·75
Depth of jaw at last molar	2·40	...	...	1·65	1·50

Now, if these measurements are compared with the measurements given above of the upper molars, there can be no doubt but that specimens *c* and *b* belong to *C. sivalensis*, and that specimen *a*, though slightly larger, also must probably be referred to the same. Specimen *e* is, however, as I have said, too small to have belonged to *C. sivalensis*, and must probably be referred to a new species; this specimen, Mr. Theobald tells me, was obtained far below the horizon of the other fossils, and therefore its specific distinctness is the more probable. The depth of the jaw of this specimen is absolutely less than that of *C. giraffa*, but is really proportionally greater, and the species, like *C. sivalensis*, belonged to a deeper-jawed type; thus in *C. giraffa* the length of the last molar exceeds the depth of the jaw by 0·1 inch, while in specimen *e* the depth of the jaw exceeds the length of the last molar by 0·1 inch.

The penultimate tooth of specimen *c* bears a small tubercle in the outer valley, as is the case in the figured specimen *a*; the last molar, as in Falconer's specimen *b*, contains no tubercle in the anterior valley, but has a very small one in the

posterior valley, which does not exist in Falconer's specimen; in the living Giraffe the first molar has a tubercle.

The next tooth which requires notice is a detached last lower premolar of the right side; it agrees precisely in form with the corresponding tooth of the specimen *a* (which is drawn in fig. 14, plate 7, of the above-quoted volume of the "Palæontologia Indica"), but exceeds that tooth in length by 0·37 inch, and is therefore too large to have belonged to *C. sivalensis*, and seems to indicate a third and larger species of Siwalik Giraffe.

The detached first lower molar mentioned in the list of specimens, is of nearly the same size as the corresponding tooth of *C. giraffa*, and doubtless belonged to *C. sivalensis*; it carries a large accessory tubercle in the outer valley.

The penultimate left lower premolar which, I think, may possibly have belonged to a small individual of *C. sivalensis* differs somewhat from the corresponding tooth of *C. giraffa*, and approaches the form of the corresponding tooth of *Sivatherium*, and of the same tooth in the jaws which I refer to *Hydaspitherium*. The hinder barrel of the tooth is very like the same part in *C. giraffa*, with the exception that both the inner and outer columns are somewhat more elongated; the outer column of the anterior barrel is also very similar; the inner side of this barrel is, however, very different. In the living Giraffe, the inner column of the anterior barrel is a simple flattened cone, placed immediately on the inner side of the outer column, there being consequently a central enamel pit in this column; the anterior extremity of the outer barrel curves round to form a simple wall bounding the anterior side of the tooth. In the fossil specimen, on the other hand, there is no separate inner column; the fore-and-aft extremities of the outer column bending round to the inner side, and leaving an open valley between them leading into the central enamel fold; the posterior one of the inner columns of the anterior barrel is simple, while the anterior one forms a large cone, with a central enamel island. The crown of the tooth is low (brachydont), and shews that the tooth belonged to the true Giraffes and not to the Sivatherioids, in which the crowns are tall (hypsodont). The general arrangement of the anterior barrel is very similar to that which occurs in *Sivatherium*, and in the jaw which I have referred below to *Hydaspitherium*; in the two latter genera, however, the antero-internal column of the tooth has its enamel fold forming a cleft on the inner side, and not a median pit.

The dimensions of this tooth are compared below with the corresponding tooth of *C. giraffa*, and I have also added the measurements of the penultimate lower molars of *C. sivalensis* and *C. giraffa*, for relative comparisons:—

	C. siv. Inches.	*C. giraf* Inches.
Length of penultimate premolar	1·10	0·95
Width of " "	0·70	0·86
Height of crown of penultimate premolar	0·62	0·85
Length of penultimate molar	1·10	1·15
Width of " "	0·90	0·99

It will be observed from the above measurements that the present premolar is relatively longer than in the living Giraffe; in the latter the penultimate lower premolar is considerably shorter than the penultimate true molar; while in *C.*

sivalensis the two teeth are of the same length; moreover, from the width of the premolar, it seems probable that that tooth belonged to a smaller individual than that to which the true molar belonged; and it therefore follows that the penultimate premolar was probably longer than the penultimate molar.

The above-mentioned specimen is, as I have said, rather small for *C. sivalensis*, and yet, I think, it may probably have belonged to a small individual of that species. The next specimen to be noticed consists of the corresponding tooth of the left side, together with the anterior premolar. There is considerable difference between the size of these teeth and that of the last, and yet I should not have thought from this alone that we ought to refer the present specimens to a distinct species; another character, however, to be shortly noticed, shews us that this must have been the case.

The hindmost of these teeth is almost identical in form with the last specimen, the only difference being that the antero-internal column has its enamel fold forming a cleft on the inner side, as in *Sivatherium*, and not a central pit, as in the last specimen. Such a variation in a tooth so liable to vary as an anterior premolar cannot be taken as having any great specific value.

The first premolar is a simple tooth consisting of two main columns in the same antero-posterior line, and a smaller talon-column in front. In the recent Giraffe there is no anterior talon-column; but a small one occurs in *Sivatherium*. Below I have given the dimensions of this specimen, together with the dimensions of the last premolar and two first molars of the lower jaw of *C. sivalensis*, described by me in the volume of the "Palæontologia Indica" above referred to (p. 41), as being the largest specimen known; in the second column I have added the corresponding dimensions of the living species:—

	Fossil. Inches.	*C. giraf.* Inches.
Length of second molar	1·25	1·15
Width of " "	1·00	0·90
Length of first molar	1·30	1·00
Width of " "	1·00	0·90
Length of last premolar	1·15	0·90
Width of " "	0·90	0·80
Length of penultimate premolar	1·40	0·95
Width of " "	0·81	0·86
Height of " "	0·75	0·85
Length of first premolar	0·96	0·70
Width of " "	0·51	0·55
Depth of jaw at first premolar	1·20	1·70

From the above measurements it will be seen that the present teeth are not too wide to have belonged to *C. sivalensis;* one very important point, however, is against the present specimen belonging to that species. It will be seen from my previously mentioned notice of the lower jaw of *C. sivalensis* that at the second molar that specimen was three-quarters of an inch deeper than the jaw of *C. giraffa*, while the present specimen at the penultimate premolar is half an inch less deep; this, therefore, pretty conclusively proves that the present specimen could not have belonged to *C. sivalensis*, but to a second species with a mandible even more slender than that of the living species; the specimens are too large to

have belonged to the same species as the small specimen I noticed above; but they might have belonged to the same species as the one that has the large detached lower premolar; this, however, we cannot be sure of until we know the form of the jaw to which the latter belonged.

Reverting once more to the premolars, it may be remembered that in the above-mentioned notice in the "Palæontologia Indica," I called attention to the less generalized form of the ultimate lower premolar of *C. sivalensis*, and I have now to add (irrespective of the question of species) that this lengthening of the premolars was common to the whole series in all the fossil Siwalik Giraffes as far as we know; moreover, in their form the two anterior teeth in question approach those of *Sivatherium* and its allies, shewing a closer connection between the two genera. The brachydont form of the teeth under consideration shews that they belong to the true Giraffes. I shall hope to obtain further specimens to indicate the affinity of the new, slender-jawed form, and do not therefore assign any name to the species at present.

Whether any of the lower premolars in question belonged to *Camelopardalis sivalensis*, or whether they belonged to some other nearly allied animal, is in great part immaterial to the real interest of the specimens, which conclusively prove that there existed at least one species of Giraffe in the Siwalik period, of which the lower premolars manifested affinity with the *Sivatherium*-like animals, while in the slenderness of its lower jaw, and in the brachydont character of its teeth, it was most nearly related to the living Giraffe. We have also seen that there appears to be good evidence of three Siwalik species of Giraffes, one very large, one of the size of the living species, and one much smaller; other specimens are much needed to throw further light on the first and second species.

The only tooth requiring notice here, which belongs in all probability to *Camelopardalis sivalensis*, is a third lower milk-molar; this tooth belongs to the right ramus of the mandible; it is a three-barreled tooth, each barrel containing two columns, and the anterior barrel being the smallest of the three; these two latter characters serve to distinguish the tooth from the third lower true molar, in which the hinder barrel consists only of one column, and is consequently the smallest of the three; the general form of the barrels is very similar to those of the permanent molars, the smaller size being the chief distinction; both of the valleys on the external side contain accessory tubercles. The length of the tooth is 1·2 inch, and its width 0·6 inch; I may observe here that this tooth is somewhat longer and narrower than the penultimate permanent lower molar, and also exceeds the length of the penultimate upper molar in the smaller specimen noticed above, by the same extent as it does the lower molar. This is about the proportion that occurs in living Ruminants, and is noticed here, as being of importance in referring certain teeth to be described immediately to their proper owners.

In addition to all the above-mentioned teeth, there is an antepenultimate lower premolar of large size, which belongs to some Giraffe-like animal, but not to the same species or perhaps genus as any of the other teeth; the tooth is upwards of an inch and a quarter in length, which is longer than the corresponding teeth of the large jaw referred below to *Hydaspitherium*, and which, therefore, belonged

to a very large animal. The tooth is brachydont, and the enamel is less rugose than in any of the Sivatherioids, and I therefore refer it to the Giraffes. The tooth posteriorly has a simple oval-shaped pit on its summit equal to about one-third the whole length; anteriorly it has a simple trenchant edge; it is therefore different in form from the corresponding tooth of either the Giraffes or Sivatherioids, and probably indicates a new genus, though I can at present say nothing more definite in regard to it.

We have now to turn our attention to the genus *Hydaspitherium*, of the upper molars of which Mr. Theobald has sent a considerable number of specimens from the Punjáb. In a forthcoming memoir on the cranium of *H. megacephalum* now in the press,[1] I have shortly noticed the upper teeth of that species, as well as a single detached specimen of an upper molar, and I have also pointed out the characters which distinguished these teeth from the molars of *Sivatherium*. The new specimens of upper molars have conclusively proved the existence of at least one new species, while another species is known upon the evidence of a lower jaw.

The notices of the specimens of this genus will be somewhat short, as many of them will be figured on a future occasion.

The first specimen that requires notice is a detached left upper molar which is a typical specimen; this tooth is distinguished from that of *Sivatherium giganteum* by its smaller size, by the rugosity of the enamel being less coarse, by the absence of foldings in the central enamel island, and by the form of the external surface or dorsum. This latter character it will be necessary to examine rather more closely. In the upper molars of *Sivatherium*, the dorsum of the hinder barrel carries three bold ridges or costæ, of nearly equal size; the dorsum of the fore barrel contains two similarly bold ridges or costæ. In typical specimens of the upper molars of *Hydaspitherium megacephalum*, the mesial ridges or costæ are very much less prominent; the one on the hind lobe being especially indistinct.

Among the specimens obtained this year are the two last upper molars of the right side, which agree exactly in size with the last-mentioned tooth; in these specimens the costæ are still more indistinct on the dorsa of the hinder lobes, this surface being indeed almost evenly concave, and exceedingly different from the same surface in the molars of *Sivatherium*. Still, the difference in the form of these teeth and of the typical molars of *H. megacephalum* is so slight that I for the present, at all events, consider it best to refer these molars to that species, classing them only as a variety. In the table below I have given the measurements of the single typical tooth which I call variety *a*, and in the second column those of the two aberrant teeth which I call variety *b*; in the third column I have given the dimensions of the two last molars of *S. giganteum*—

	Hydasp. var. *a.* In.	*Hydasp.* var. *b* In.	*Sivath.* In.
Length of last molar	1·56	1·62	2·00
Width of " "	1·60	1·63	2·38
Length of penultimate molar . . .	...	1·59	1·68
Width of " "	...	1·70	2·20
Height of " "	...	1·20	...

[1] Palæontologia Indica, Ser. X, Vol. I, pt. 3.

The two conjoined teeth shew a faint cingulum at the base of the inner columns, which is not observable in the isolated tooth or in the teeth of the cranium of *H. megacephalum*. We have now to consider several other specimens of upper teeth, which have considerable resemblance to the two last specimens, but which are of larger size, and which still further diverge from the *Sivatherium* type, and which must, I think, undoubtedly be referred to a second species of the genus *Hydaspitherium*, for which I propose the name of *H. grande*. The specimen which I will here select for notice is a penultimate upper molar of the left side from the Punjáb. This tooth agrees with the teeth of the last specimen in its general form, the dorsum of the posterior barrel overlapping that of the anterior column (owing to the oblique position in which they are placed), and the enamel being rugose, though less so than in *Sivatherium*, and there being no crenulation of the enamel in the central pits.

The chief differences of this tooth from those of variety *b* of the last species, irrespective of size, are, that the crown is relatively much higher; that the anterior costa of the dorsum of the hinder lobe is more prominent and curves more forwards, and that there is no median costa on this surface, which is more concave than in the last specimen; the median costa on the dorsum of the fore lobe is also much less developed; there is no trace of any cingulum on the internal surface of this tooth, nor of any tubercle in the median valley; the summits of the lobes have hardly been touched by wear. The dimensions of this specimen are compared below with the above described penultimate upper molar of variety *b* of *H. megacephalum*—

	H grande.	*H. mega.*
	In.	In.
Length of crown	1·80	1·59
Width of "	1·80	1·70
Height of "	1·60	1·20

This tooth, therefore, is squarer than that of *H. megacephalum*, and, differing by only 0·1 inch in width, differs by 0·4 in the height of the crown. These differences, I think, amply justify specific distinction; these teeth from the absence or slight development of the median dorsal costæ present no resemblance to those of either *Sivatherium* or *Bramatherium*. They are nearest, of course, to the variety *b* of *Hydaspitherium megacephalum*, the latter forming a connection between the present specimen and var. *a* of *H. megacephalum*, and those again with *Sivatherium*. As I have before hinted, it is not impossible that the teeth of variety *b* of *H. megacephalum* may really belong to a distinct species, though I do not think we are justified in making any distinction on the evidence of these teeth alone, as they are so close to those of variety *a*.

In addition to the above specimens, Mr. Theobald has obtained three detached upper molars of the same species from the village of Asnot, as well as the two last upper milk-molars of the right side, and two detached specimens of penultimate upper milk-molars of the same side, which from their size and form I have little doubt must be referred to *H. grande*. The ultimate milk-molar repeats the characters on a smaller scale of the larger permanent teeth; the penultimate milk-molar has the first barrel produced into a point anteriorly, which proves that the

two teeth belong to the milk series. The dimensions of the two teeth are as follows:—

	In.
Length of last milk-molar	1·50
Width of " "	1·30
Length of penultimate milk-molar	1·52
Width of " "	1·00

Having now examined all the types of upper molars of this group of animals contained in Mr. Theobald's collection, it now remains to consider two lower jaws of two species of Sivatherioid animals, which cannot be referred to *Sivatherium giganteum*; both specimens are from the Siwaliks of the Punjáb.

The first specimen consists of the greater portion of the right ramus, the only missing parts being the extremity of the coronoid process, and the part in front of the first premolar; the whole of the dental series is complete and but little worn.

I shall here notice this specimen very shortly, as I shall figure it on a subsequent occasion. The ascending portion of the ramus has its anterior border almost at right angles to the axis of the horizontal portion, which distinguishes the jaw from that of *Camelopardalis* (the corresponding part of the jaw of *Sivatherium* is unknown). The horizontal portion is slender and bows outwards to a great extent in the middle, so that the part immediately below the hinder barrel of the first molar is by far the most prominent point in the whole of this side of the jaw. The two latter characters at once distinguish the specimen from the mandible of *Sivatherium*, which is very deep, and which is slightly concave externally.

The teeth are distinguished from those of *Sivatherium* by the costæ on the internal surfaces, and especially those of the hinder barrel, being much less prominent and bold; and by the reticulations of the enamel being finer, as well as by the greater obliquity of their dorsa to their long axes; in *Sivatherium* a rod placed on the last molar will touch both median costæ, while in this specimen it will touch the median costa of the second barrel, and the posterior costa only of the first barrel.

The premolars are very like those of the fragment of a jaw referred above to *Camelopardalis*, but are much larger, and relatively higher, and the enamel is more rugose. In the following table I have given the dimensions of this specimen, of the mandible of *Camelopardalis*, and of *Sivatherium*; the latter dimensions are taken from a cast of the specimen figured on plate twenty-one of the first volume of the "Palæontological Memoirs," the original of which is in the British Museum:—

	Camelo.	Specimen.	*Siva.*
Length of six molars	6·50	10·30	...
" four last teeth	4·10	7·70	9·00 *
" from angle of jaw to distal end of molar series	10·50	14·50	...
Height from angle to summit of condyle	5·80	7·50	...
Depth at middle barrel of last molar	1·70	3·30*	4·70
" at hind barrel of first molar	1·75	2·52	3·45
" at second premolar	1·55	2·40	3·00
Thickness at first molar	1·00	1·95	2·15
Height of unworn last molar	...	1·70	...

The jaw of *Sivatherium* referred to is probably that of a male, other specimens being slightly smaller; the smaller or female specimens, however, have the same form and proportions as the larger. From the above measurements and comparisons there can be no question as to the distinctness of the specimen from *Sivatherium*.

The teeth are readily distinguished from those of *Bramatherium* by their larger size and greater proportionate height; and from those of *Vishnutherium* by the absence of any cingulum or accessory tubercle, as well as by their much greater size.

There now only remains the genus *Hydaspitherium* of described genera to which the specimen can belong; and from the slight development of the costæ on the dorsa of the upper molars of that genus, and of the lower molars of the present specimen, I think it probable that the latter should be referred to that genus.

With regard to the question of species: the above-referred to cranium of *H. megacephalum* is, from the fact of its bearing horns, no doubt that of a male individual (the female of the allied genus *Sivatherium* being hornless); now, in that specimen the length of the last five teeth of the molar series is only 6·1 inches, while the length of the last five teeth in the present specimen is 9·2 inches; this clearly shews that the specimen could not have belonged to that species.

Then with regard to *H. grande*: this, as we have seen, is only known from upper molar teeth, and there is therefore great difficulty in saying whether or no this specimen belongs to that species; another mandible, however, to be noticed immediately in the character of its lower molars, approaches nearer to the upper molars of *H. grande*, and I have accordingly provisionally referred the second specimen to that species. The present specimen must therefore belong to a third species, for which I propose the name of *H. leptognathus*, with the proviso that subsequent discoveries may render it necessary to change the generic prefix.

The present specimen indicates the existence of a slender-jawed Sivatherioid, which in the form of its jaw is a connecting link between the stout-jawed *Sivatherium giganteum* and *Camelopardalis sivalensis*, in which the jaw is stouter than in the living Giraffe. The perpendicular inner border of the ascending portion of the present jaw is quite peculiar, as far as is yet known.

We have now to consider the portion of a mandible which, I think, may very probably belong to *Hydaspitherium grande;* this specimen comprises a portion of the left ramus of the mandible containing the three true molars and the last premolar; the jaw is broken off posteriorly immediately behind the last molar, and anteriorly some distance in front of the premolar; the teeth are only slightly abraded by wear.

This mandible differs from the last specimen by being much deeper, and by being slightly concave instead of convex on the outer surface; in both of these respects it approaches to the jaw of *Sivatherium giganteum*. The form of the teeth, however, at once distinguishes the specimen from the last-named genus, and also from *H. leptognathus*. The dorsa, or internal surfaces, of the teeth are placed still more obliquely to the long axis of the jaw than in *H. leptognathus;* and the

median costæ are still less developed, those of the hinder barrels being indeed almost obliterated; if a rod be laid on the dorsa of the barrels of the last molar, it only touches the posterior costæ of the barrels, and not the median costa of either barrel, which shews that the form of the teeth is still further removed from that of the teeth of *Sivatherium* than are the teeth of *H. leptognathus*. Perhaps the most distinguishing character of the specimen is the form of the dorsum of the anterior barrel of the last premolar; this surface is fan-shaped, narrower below than above, and nearly flat, the median costa being very slight, and the anterior costa forming a curved boundary to the dorsum. In the corresponding tooth of *Sivatherium* the median dorsal costa is very large, and is the most prominent part of the whole surface, while at the same time the tooth of *Sivatherium* is less fan-shaped. The corresponding tooth of *Hydaspitherium leptognathus* is absolutely taller and narrower than the present specimen, which alone would be a sufficient distinction. I have given below the dimensions of the last lower premolars of the three lower jaws; the tooth of *S. giganteum* is rather more worn down than the others, and therefore is proportionally somewhat squarer—

	Siv.	*H. lepto.*	*H. grande.*
	In.	In.	In.
Width of dorsum of last premolar	1·40	1·05	1·3
Height of " "	1·72	1·60	1·4

The other dimensions of the specimen are as follows:—

Length of four last teeth	7·7
Depth at middle barrel of last molar	3·7
" at hind barrel of first molar	3·7

From the above comparisons, it is quite evident that the specimen cannot belong to *Sivatherium* or to *H. leptognathus;* the size of the specimen, apart from other characters, distinguishes it from *Bramatherium* and *Vishnutherium*. The specimen, being as large as the jaw of *H. leptognathus*, for the same reasons cannot belong to *H. megacephalum*.

There only remains therefore *H. grande* to which the specimen can belong; now, in the flatness of the dorsa of the molars of the present specimen, as well from their obliquity to the long axis of the jaw, these teeth agree with the upper molars referred to above as forming the new species *H. grande;* the size of the upper and lower molars also agrees well together, and I have accordingly thought it extremely probable that the two belong to the same animal. I wish it, however, to be understood that I cannot be certain in this identification, and that it may subsequently be necessary to refer the lower jaw to a new species or even to a new genus.

The animal to which this jaw belonged was doubtless of the massive type of *Sivatherium*, and therefore widely distinguished from the slender-jawed *H. leptognathus* and the true Giraffes; in the form of its teeth the animal was nearer to the former species, though it diverged still more widely in the form of the inner surfaces of the molars from *Sivatherium* and the Giraffes.

The only other specimen among the collection of teeth of Sivatherioid and Giraffoid animals is a last lower milk-molar of the left side; this specimen I cannot with any confidence refer to any particular species, and I here merely

desire to call attention to it. The specimen in question is far larger than the lower milk-molar which I have referred to *Camelopardalis sivalensis* and cannot belong to that species; it also differs very considerably in form from that specimen, from which I think that it does not belong to that genus.

The tooth is composed of three complete barrels, the hindmost of which is the largest: these two characters assure us that the specimen is a last milk-molar, and not a last true molar. The outer columns of the barrels are set very obliquely to the long axis of the jaw, and the median costa on the one perfect dorsum is slightly developed; in these respects the tooth differs from the true molars of *Camelopardalis* and agrees with those of *Hydaspitherium.* Each of the valleys on the outer side contains a large and pointed tubercle reaching to half the height of the crown. The length of the specimen is 1·9 inch and its greatest width 0·94 inch.

The tooth is slightly longer than either of the two anterior molars of *H. leptognathus,* which is the same relation as exists between the corresponding teeth of *Camelopardalis sivalensis* and ordinary Ruminants: and I think it extremely probable that it should be referred to the former species; it is true that the permanent molars of *H. leptognathus* have no accessory columns like the milk-molar in question, but it not unfrequently happens that the lacteal series does differ from the permanent series in certain points of detail, such differences generally consisting in that the lacteal molars retain ancestral characters which have been lost in the permanent series.

Among the whole of the specimens sent down by Mr. Theobald from the Siwaliks of the Western Punjáb, I cannot find any remains which I can with certainty refer to *Sivatherium giganteum,* and it is not improbable that the range of that animal did not extend into the area in question, where it was replaced by the allied genera; no species of this group have hitherto been found in Sind. Among Mr. Theobald's collection there are a considerable number of the limb bones of various Sivatherioid animals, which are generally smaller than those of *S. giganteum,* and which most probably belonged to some of the above described smaller species. I have not yet had time to examine those bones in any detail.

PERISSODACTYLA.

Genus: RHINOCEROS.

During the present and past year the Indian Museum has acquired a large series of specimens of the osteology and dentition of the fossil species of this genus, which have been obtained by the exertions of Mr. Theobald in the Siwaliks of the Punjáb, and most especially from the highly fossiliferous beds of the village of Asnot in the Jhelam district.

Among these specimens are the complete adult molar series of *Rhinoceros sivalensis,* the upper milk dentition of *R. palæindicus,* and a complete ramus of the mandible with the symphysis of the same species, and, most important of all, a large series of the upper and lower dentition of the new species *R. planidens,* which appears to be confined to the Punjáb. No specimens of *R. platyrhinus* occur either in the present or in previous collections from the Punjáb, and it is not improbable that this species did not occur in that area.

In the present notice I shall only refer to certain upper teeth of *R. planidens*, which are far more perfect than the specimens of upper molars described at page 23 of "Molar Teeth and Other Remains of Mammalia,"[1] and upon the evidence of which the species was founded; and also to a portion of the lower jaw of the same species. The new specimens incontestably prove the distinctness of the species.

Of the two specimens of upper molars which I have selected for notice here, one is the penultimate tooth, and the other the last tooth of the right side. Both teeth are quite complete and in a middle state of wear; they are of such a size that by this character alone they might be well distinguished from *R. sivalensis*, which is the only one of the Siwalik species of *Rhinoceros* with which they have any affinity.

Both of the original specimens on which the species was founded lacked the external surface of the crown, the form of which has been therefore hitherto unknown. In the present specimens we find that the dorsum or external surface is produced into a bold buttress at its antero-external angle, and that the rest of that surface is nearly flat; the presence of this buttress alone is sufficient to distinguish these teeth from those of *R. platyrhinus*.

The other characters of the penultimate tooth are similar to those of the previously-acquired specimens, and need no further notice here. The last tooth, allowing of course for its different form, agrees in general characters with the previous specimen; it is readily distinguished from the corresponding tooth of *R. sivalensis* by its vastly superior size, and by having a very wide cingulum surrounding the outer and inner sides of the anterior collis, and which is continued into the median valley to form a low and wide tubercle at the entrance, of which there is no representative in the corresponding tooth of *R. sivalensis;* the tooth has a small crochet and a large antecrochet.

The dimensions of these two teeth are compared below with the same dimensions of the corresponding teeth of *Rhinoceros sivalensis* :—

	plani. In.	*R. siva.* In.
Penultimate molar.		
Length of anterior surface	3·20	2·70
„ of internal surface	2·45	1·82
„ of posterior surface	2·60	2·34
„ of external surface	3·40	2·50
Height of crown	2·22	2·10
Last molar.		
Length of anterior surface	3·20	2·30
„ of internal surface	2·95	1·90
„ of posterior surface	3·20	2·35
Height of crown	3·05	1·75

The difference in size is, therefore, so great that from this alone there would be no doubt as to the specific distinctness of *R. planidens*, which indeed seems to have been next in size to the largest specimens of *R. platyrhinus*, the largest of any species of *Rhinoceros* with which I am acquainted; the dorsum of the penultimate molar measuring upwards of four inches in length.

[1] Palæontologia Indica, Ser. X, Vol. I, pt. 2.

In addition to these upper molar teeth Mr. Theobald has sent down the symphysis and part of one ramus of a mandible of a species of *Rhinoceros*, which was found with the upper molars, and which I have no doubt from its size belongs to the same species. Before going further, it may be well to remind the reader that the mandibles of three species of Siwalik *Rhinoceros* are figured in the "Fauna Antiqua Sivalensis," and were referred by Falconer to his three species *R. sivalensis*, *R. palæindicus* and *R. platyrhinus*; I do not know on what grounds the lower jaws were referred to their respective species, which were founded upon crania; there is, however, no doubt but that these three jaws belonged to the three above-mentioned species, irrespective of the question of assigning each to each. Now, these three kinds of mandibles all differ from the present specimen, and there is, therefore, every presumption in favor of the Punjáb lower jaw having belonged to the Punjáb *R. planidens*.

The portion of the lower jaw in question consists of the symphysis, and a part of the right ramus containing the three last premolars and the first true molar; on either side of the symphysis there is a single huge incisor, that of the right side being broken off near its summit, and that of the left at the summit of the alveolus; there are no inner incisors. The single incisor has a flattened surface superiorly, looking upwards and inwards, while the inferior and external surfaces are rounded, the tooth is strongly curved upwards, and extends above the level of the plane of the grinding surfaces of the molars; the jaw is of great vertical depth.

The lower jaw of *R. sivalensis* (F. A. S., pl. 74, fig. 6) has no incisors, and is therefore quite unlike this specimen. In the lower jaw of *R. platyrhinus* (F. A. S., pl. 75, fig. 10), there are two small inner incisors, as well as larger outer incisors; the latter are directed less upwards, and are straighter and smaller than those of the present specimen.

The lower jaw of *R. palæindicus* (F. A. S., pl. 74, figs. 3 and 4) agrees with the present specimen in having the outer incisors only; the latter are, however, smaller and shorter, and are directed very slightly upwards, so that only their extremities reach the level of the grinding surface of the molars; and the jaw is shallower and the symphysis shorter.

In the following table I have compared together the dimensions of the present specimen, with the corresponding dimensions of the mandible of *R. platyrhinus* and *R. palæindicus*; the latter are taken in part from the description of the plates of the "Fauna Antiqua Sivalensis," and in part from specimens in the Indian Museum:—

	R. plan. In.	*R. plat.* In.	*R. pal.* In.
Depth of jaw at last premolar	4·5	...	3·4
Length of symphysis	6·4	6·9	4·5
Vertical diameter of outer incisor .. .	1·8	0·7	1·1
Transverse " "	2·4	1·5	1·3
Length of incisor (broken in *R. planidens*) .	3·5	2·1	1·9
" of three last premolars . . .	5·1	3·8	4·7

No other *Rhinoceros* that I have seen has lower incisors at all approaching in size to those of the present specimen; in correlation with these enormous lower incisors

we should expect that the upper incisors were likewise of unusual size in *R. planidens*, and such appears to have been the case. From the district where the upper molars and lower jaw of *R. planidens* were obtained, Mr. Theobald has obtained two upper incisors of a *Rhinoceros* of gigantic size, which I have no doubt belonged to the same species; the length of one of these specimens is upwards of 4·3 inches, its thickness 1·5 inch, and the height of its crown 1·9 inch. The upper incisors of the other Siwalik species of *Rhinoceros* are not known; the present specimen is, however, far too large to have belonged to *R. sivalensis* or *R. palæindicus*, while *R. platyrhinus* is not known to occur in the Punjáb, and if we may judge from Colonel Baker's cranium of this species seems not to have had permanent upper incisors.

The above comparisons point most clearly to the specific distinctness of the gigantic fossil *Rhinoceros* of the Punjáb; in its upper molars this species approaches nearest to *R. sivalensis*, but is distinguished by their larger size and their bold cingulum and tubercle in the median valley; in the number of its lower incisors the new species agrees with *R. palæindicus*, but is distinguished by their curved form and much greater size.

Genus: LISTRIODON.

Of this genus, which has still an *incerta sedes*, Mr. Theobald has obtained an upper molar of a very small species quite distinct either from the Indian *L. pentapotamiæ* or the European *L. splendens*, or *L. lartetii*, and which must be referred to a new species. The specimen was obtained from the Siwaliks of the village of Jabi in the Punjáb, and will be described and figured on a future occasion; I propose to call the species after its discoverer, *L. theobaldi*.

RODENTIA.

Genus: HYSTRIX.

At page 706 of the fourth volume of the "Journal of the Asiatic Society of Bengal," in a list of Siwalik fossils given by Falconer and Cautley, there occurs the name of the genus *Hystrix*, as having been obtained with the other specimens. The name of the genus again appears on page 293 of the fifth volume of the same Journal, and also in the Introduction to the "Fauna Antiqua Sivalensis" (Pal. Mem., Vol. I, p. 23). I can find, however, no further mention of the genus in Falconer's papers, nor any notice of the specimen on which the determination was made; this specimen (or specimens) has, in all probability, been lost.

With the exception of the occurrence of the name in the above lists, we have hitherto known nothing of the occurrence of *Hystrix* in the Siwaliks; towards the end of last year, however, Mr. Theobald forwarded to the Indian Museum a portion of the mandible of a species of this genus, obtained from the Siwaliks of the village of Asnot, which forms the object of the present preliminary notice.

The specimen consists of the middle portion of the right ramus of the mandible containing the two first molars, and the sockets of the last premolar and last molar; the cutting extremity of the incisor of the same side was also obtained.

In this notice I shall content myself with pointing out the main distinctions of the teeth of the fossil specimen from those of *H. leucura*, which are indistinguishable from those of *H. cristata*. The dimensions of the two first molars of *H. leucura* are compared below with those of the fossil teeth :—

	Fossil. In.	Recent In.
Length of two first molars	0·75	0·71
" of first molar	0·39	0·35
Width of " "	0·33	0·29
Length of second "	0·36	0·36
Width of " "	0·31	0·28

From these dimensions it will be seen that in the fossil jaw the first molar is longer than the second, while precisely the reverse of this occurs in the recent jaw; the first molar of the fossil is considerably larger than that of the recent jaw, while the second molars of the two are of the same length, but that of the fossil is wider. Since the smallest of the fossil teeth is as large as the largest of *H. leucura*, the matter of size will distingush the fossil form from the two smaller Indian species, *H. bengalensis* and *H. longicauda*.

Now, for the form of the teeth, in *H. leucura* the lateral enamel fold at the middle of the inner side runs only for a very short distance at right angles to the long axis of the tooth, and is connected for a long time with the fold at the antero-external angle of the crown, and is isolated after its severance; in the fossil jaw this fold runs for some distance at right angles to the same axis, is never connected with the antero-external fold, and is not isolated at all in the specimen. Other differences occur in the form of the grinding surface, which require a figure for their explanation; as minor differences, the surface of attrition of the incisors in the fossil jaw is more concave, and the muscular ridges of the latter are much more strongly marked than in the living species. These differences sufficiently distinguish the Indian fossil *Hystrix* from the living species of the genus.

The only fossils of the genus with which I am acquainted are certain fragmentary specimens from the Val d'Arno[1] of which the species is not determined; *H. refossa* from the sub-volcanic alluvium of Puy de Dome[2]; *H. primigenia* from the upper miocene of Attica[3]; and *H. venusta* from the pliocene of North America.[4]

I can say nothing with regard to the unnamed species: *H. refossa* has the enamel islands unusually numerous, and the external fold very slight, and therefore differs from our specimen: *H. refossa* is considered by M. Pomel to be an agonti.[5] In *H. primigenia* the large inner enamel fold of the lower molars agrees in the matter of length with the same fold in the fossil Indian species, but it seems to be sooner isolated; the form of the minor folds is also different in the two, and

[1] Cuvier: "Ossemens Fossiles," 4th Ed., Vol. VIII, p. 128.

[2] Gervais: "Zoologie et Paléontologie Françaises," pl. XLVIII, fig. 11.

[3] Gaudry: "Animaux Fossiles de l'Attique," pl. XVIII, fig. 2.

[4] Leidy: "Extinct Mammalia of Dakota and Nebrasca," p. 343, pl. 26, figs. 23 & 24; the species is there named *H. venustus*, which I have ventured to alter to *H. venusta*, *Hystrix* being feminine.

[5] Pictet: "Traité de Paléontologie," Vol. I, page 255.

in *H. primigenia* the two first lower molars are of equal length. The molars of *H. venusta* are very large, and the folds simpler than in our specimen.

The Indian fossil cannot, therefore, be referred to any named species with which I am acquainted, and I propose therefore to call it *H. sivalensis*.

Genus: RHIZOMYS, nov. sp. (?).

From certain beds at the village of Jabi in the Punjáb, which Mr. Theobald classes as middle Siwalik, I have received two detached rami of the mandible of an apparently new Rodent. Each of these rami contains three molars and no premolar; these molars have a single deep enamel fold on the outer side, and three smaller folds on the inner side, which are well apparent in the worn teeth; the last molar is longer than the penultimate; the molars have distinct roots; and the jaw is stout and has well-marked ridges for muscular attachments. The length of the three molars is 0·6, and the depth of the jaw at the second molar 0·5 inch.

To determine the group of Rodents to which these jaws belong I have made use of the classification of the Order *Rodentia* or *Glires* published by Mr. Alston in the "Proceedings of the Zoological Society of London" for 1876. From that memoir the following facts may be gathered as to the number and form of the lower molar teeth in this order:—

In the Sub-orders GLIRES DUPLICIDENTATI and G. HEBETIDENTATI there are always premolars.

In the Sub-order GLIRES SIMPLICIDENTATI, the Sections SCIUROMORPHA and HYSTRICOMORPHA always have premolars. In the remaining Section, MYOMORPHA, premolars may or may not be present. It is therefore clear that our specimens can only belong to this last section.

In this section, the families *Myoxidæ*, *Geomyidæ*, and *Theridomyidæ* always have premolars. The families *Spalacidæ* and *Dipodidæ* may or may not have premolars, while the families *Lophiomyidæ* and *Muridæ* never have premolars. It is therefore evident that our specimens can only belong to one of the last four families.

Now, in the three last-mentioned families the molars are always either tuberculate, or carry more or less transverse ridges, and never have external or internal enamel infolds. It is, therefore, clear that our specimens cannot belong to either of these families, and they can, therefore, only belong to the remaining family, *Spalacidæ*. This family is divided into two sub-families the *Spalacinæ* and the *Bathyerginæ*; the latter group has always premolars, while the former lacks them: our specimens can, therefore, only belong to the former.

The sub-family *Spalacinæ* contains three well-known living genera, namely, *Spalax*, *Rhizomys* and *Heterocephalus*; of these, the molars of *Spalax* are distinguished from those of the present specimens by having very slight enamel folds, which exist only in the almost unworn state; the lower molars of *Heterocephalus* are distinguished by having only a single inner and outer fold. (Alston.)

There now remains only the genus *Rhizomys* to which our specimens can belong; the lower molars of that genus are characterized by having a large

external enamel fold, and two or more smaller inner folds, which persist till the crown is quite worn down. These characters agree, therefore, perfectly with the characters of our Siwalik specimens, and I can have no doubt but that the latter belong to that genus; I have compared these molars with the teeth of *R. sumatrensis*, and find that they can only be distinguished in form from the latter by the greater depth of the external fold, and by the smaller size of the first internal fold; the fossil molars are in one specimen slightly smaller, and in the other slightly larger, than those of the recent species; the fossil mandible is, however, narrower and slenderer, the incisors much smaller, and there are other differences in the form of the two mandibles which are quite sufficient to specifically distinguish the two forms; these differences will be pointed out on a subsequent occasion. I shall hope to give a figure of the fossil. The fossil teeth are larger than those of any of the other species with which I have been able to compare them: should they belong to a new species, as I think is probably the case, I shall propose to call this species *R. sivalensis*.

It may not be out of place here to observe that among Falconer's undescribed Siwalik Mammalia, there was indicated a new genus under the name of *Typhlodon*. The name only of this genus occurs in the Introduction to the "Fauna Antiqua Sivalensis" (Pal. Mem., p. 23), and from the contents it is evident that this genus belonged either to the Rodents or Insectivores; from the name *Typhlodon* I think that the genus must have belonged to the former, since the name appears to be so evidently derived from *Spalax typhlus*. This being so, and since our new *Rhizomys* belongs to the *Spalacinæ*, I think it not at all improbable that Falconer's *Typhlodon* was founded on the same *Rhizomys*. The Introduction in question was published in 1844, and a great part of it was written much earlier in India; it is, therefore, not improbable that Falconer was unacquainted at the time of writing with the genus *Rhizomys*, which was made in 1830,[1] and that finding a Rodent allied to, but distinct from, *Spalax*, he made a new genus for its reception.

The genus *Rhizomys* being confined at the present time to Asia, it was only to be expected that fossil representatives should be discovered in the pliocene of that continent; living species are found in India in the Khasi Hills, and the Sikim Terai. (Jerdon.) I believe that no fossil species of the genus has hitherto been described. An allied genus (*Myospalax*[2]) has been formed for the reception of the so-called "Quettah mole;" I cannot, however, find that this genus has been described; and I cannot, therefore, say in what respects its dentition differs from that of *Rhizomys* and *Spalax*. The genus is not introduced into Mr. Alston's synopsis.

CARNIVORA.

The remains of Carnivora are of somewhat rare occurrence in the Siwaliks, and therefore almost every specimen obtained is worthy of notice.

[1] Gray, P. Z. S., 1830, p. 95.
[2] A. S. B., Vol. XI, p. 887; XV, p. 141.

Genus: FELIS.

Of a large *Felis*, which is probably *F. cristata* of Falconer, Mr. Theobald has obtained from Asnot the patella, the distal half of the femur, several metatarsal and phalangeal bones, and the olecranon.

Of a smaller species, the radius, the calcaneum, and a portion of the left ramus of a mandible containing the alveolus of the canine, and the two premolars have also been obtained. I can at present say nothing as to the species to which this lower jaw belonged; it possibly belonged to the same species as the cranium figured on plate XXVII, fig. 1, of the fifth volume of the "Journal of the Asiatic Society of Bengal."

Genus: HYÆNA.

Of this genus Mr. Theobald has collected a tolerably perfect adult cranium, a broken adolescent cranium, exhibiting the carnassial in its alveolus, and a ramus of the mandible; all the specimens seem to belong to one species.

Genus: MELLIVORA.

In the unpublished plates of the "Fauna Antiqua Sivalensis" (Q, fig. 4), there occurs a figure of a cranium which in the Index to the Plates is named *Ursitaxus sivalensis;* now, the generic name *Ursitaxus* was proposed by Hodgson[1] for the Indian ratel, but is now disused in favor of *Mellivora; Ursitaxus sivalensis* of Falconer will therefore here and henceforth be called by me *Mellivora sivalensis.*

The above-mentioned cranium seems to be the same as that figured on plate XXVII, fig. 4, of the fifth volume of the "Journal of the Asiatic Society of Bengal" under the generic name of *Gulo:* the specimen is now in the British Museum. On fig. 6 of the same plate of the "Journal of the Asiatic Society of Bengal," a nearly complete right ramus of the mandible of the same genus is also figured; this specimen is not refigured in the "Fauna Antiqua Sivalensis," and I do not know what has become of it.

From the Siwaliks of Asnot, Mr. Theobald has sent the dental portion of a right ramus of the mandible of a species of *Mellivora*, which agrees precisely with the above-mentioned figured jaw; the specimen is somewhat larger than the mandible of *M. indica*, while the figured fossil cranium is rather smaller than that of *M. indica.* These differences in the relative size of the two fossil specimens may be merely due to sex, as there is considerable variation in the size of the sexes of many *Carnivora;* consequently the new lower jaw may probably be referred to *M. sivalensis.* Except in the matter of size, I can see no difference between the mandible of *M. sivalensis* and *M. indica*, and they must have been at all events very closely allied.

Genus: MELES (?).

In addition to the last specimen, Mr. Theobald has obtained from Asnot the left ramus of a mandible which evidently belonged to some animal allied to the badgers, though I cannot be sure of the genus. The specimen shews the base

[1] Asiatic Researches, Vol. XIX, p. 60.

of the canine, and of the second premolar (the first having disappeared), the two last premolars, and the greater part of the base of the carnassial, its summit being broken off.

The premolars are of the simple conodont type of the true badgers, while the carnassial is an extremely elongated and narrow tooth as in those animals; unfortunately its crown being broken away, I cannot compare it with the tooth of the badger. The two last premolars are of nearly equal size, and have no cingulum, which distinguishes the jaw from that of *Mellivora;* the three last premolars are in close apposition, which distinguishes the jaw from that of *Arctonyx.*

The jaw has exactly the form of that of *Meles taxus,* but is considerably larger; and I think it probable that the specimen should be referred to a new species of that genus. *Meles* is not found living in India, but occurs in Tibet and Persia,[1] and a skin was obtained by the late Dr. Stoliczka in Kashgaria, which renders it not improbable that the genus may exist in that country.

Genus: AMPHICYON.

Of *Amphicyon palæindicus* Mr. Fedden has collected in Sind a portion of a right ramus of a mandible, containing the second true molar, and the alveolus of the third; the second molar is very like the corresponding tooth of *A. major,* but the form of the masseteric fossa differs in the jaws of the two species.

Genus: HYÆNARCTOS.

Of the genus *Hyænarctos* the Indian Museum has lately received several specimens of the upper dentition, obtained by Mr. Theobald from the Siwaliks of the Punjáb; the new specimens comprise a right maxilla containing the three last teeth, a left maxilla with the three corresponding teeth, and the detached carnassials and first molars of both sides belonging to one individual.

The second specimen and the detached teeth belong to *H. sivalensis;* the first specimen, however, seems to belong to another species. The three teeth of that specimen occupy a shorter space than the same three teeth in *H. sivalensis,* the length of these three teeth in the former being 3·1 inches, and in *H. sivalensis* 3·4 inches. The most striking peculiarity of the smaller teeth is in the form of the first true molar: in *H. sivalensis* the crown of that tooth is oblong in form, while in the new specimen it is somewhat triangular, the apex being on the inner side; the inner ridge in the new specimen is also higher and shorter than in *H. sivalensis;* the carnassial and last molar are very similar in both jaws.

The first molar of the new specimen is somewhat like the first molar of *H. hemicyon* from Sansans,[2] both alike approaching the form of the corresponding tooth of the dogs and *Amphicyon;* the Indian specimen, however, lacks the inner cingulum, which occurs in the European form, and the former jaw is further distinguished from the latter by the form of the last molar, which is like that of *H. sivalensis.*

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[1] Blanford: "Eastern Persia," Vol. II, p. 44.

[2] Gervais: "Paléontologie et Zoologie Françaises," pl. 81, fig. 9.

The new specimen is unlike any other described species; and must consequently be referred to a new species, which I propose to call *H. palæindicus*.

It may be not of out of place here to notice an upper molar of this genus which has been figured by Professor Flower in the August number of the Quarterly Journal of the Geological Society,[1] and which, as well as another specimen, was obtained from the English Red Crag. The figured tooth is the first upper molar of the right side, and agrees exactly with the corresponding tooth of Mr. Theobald's specimens of *H. sivalensis;* the latter tooth being unworn and more perfect than those of Falconer's cranium of this species (with which Professor Flower compared his specimens) are more suitable for comparison with the unworn English specimen. Professor Flower mentions that "the fine striation of the surface of the enamel in lines converging to the apices of the cusps, which is beautifully seen in both the Crag teeth," is very indistinct on the more worn Siwalik teeth; Mr. Theobald's specimens, however, agree exactly in this character with the Crag teeth, and I can but adopt the opinion of Professor Flower that there is no specific distinction between the English and the first-named Indian *Hyænarctos*.

In noticing the range of the genus, Professor Flower only alludes to its occurrence in Europe and Asia; he might have added that it also occurs in the newer pliocene of South America.[2]

ALLEGED CETACEAN.

A cast of the bone referred to the Cetacea on page 103 of the ninth volume of the "Records," has been submitted to Professor Flower, who considers that it belongs to the Ungulata and not to the Cetacea; there is, therefore, at present no evidence of the presence of the latter order among the Siwalik Fauna.

THE PALÆONTOLOGICAL RELATIONS OF THE GONDWANA SYSTEM: A REPLY TO DR. FEISTMANTEL, BY W. T. BLANFORD, F.R.S., *Deputy Superintendent, Geological Survey of India.*

Introduction.—I have allowed more than a year to elapse without attempting to answer any of Dr. Feistmantel's remarks in the "Records of the Geological Survey," although I cannot admit that in his reply[3] to my first paper[4] he has either confuted my arguments, or, except in one case,[5] of which I think he has exaggerated the importance, and twice when I had been misled by his own mistakes, shown me to be in error. My reasons for waiting were partly that I had other matters of greater urgency to attend to; partly that I hoped the irritation which

[1] Vol. XXX, p. 534.

[2] O. C. Marsh: "Address to American Science Association," Newhaven, 1877, p. 46.

[3] Rec. G. S. I., vol. IX, p. 115.

[4] Ib. pp. 79.

[5] This refers to the presence of *Cycadeaceæ* in the lower Gondwánas. The only error I committed was in overlooking the fact that *Noeggerathia* is classed by many writers as a Cycad. The affinities of this plant are by no means determined with certainty.—See Geol. Mag. 1876, p. 489; 1877, pp. 190, 431; Rec. G. S. I., vol. IX, pp. 118, 140.

Dr. Feistmantel exhibited at finding his conclusions were not immediately accepted might subside; partly, that I feel, in this discussion, that the contest is unequal. Dr. Feistmantel has the enormous advantage of a thorough acquaintance with the literature relating to fossil plants, whilst I possess but a very imperfect knowledge of the subject.

Of the three different papers which Dr. Feistmantel has published in reply to my remarks, it is my intention to notice only one at any length. One of the three papers, that published in the "Neues Jahrbuch" for 1877,[1] I have only seen since this paper was first written, the number of the "Jahrbuch" which contains it having, through some error of the agents or of the post, failed to reach the Survey library at the usual time. The second paper appeared in the "Geological Magazine" for November 1876.[2] The publication of these two papers is, I think, a misfortune, and I believe Dr. Feistmantel has seen cause to regret having written and published them.

The paper in the fourth number of the "Records" for 1876 stands in a very different position; it appears as an official document, and should it not be shown to be erroneous, it will certainly be supposed by geologists generally to have been accepted by the Geological Survey of India, and consequently as entitled to more weight than an occasional paper printed, without any official supervision, in a scientific journal. At the same time I cannot profess to answer every paragraph in detail. Dr. Feistmantel is a voluminous writer, and although there are many statements open to question in the numerous papers which he has already contributed to the Survey publications, I do not see the use of attempting to answer them all; I merely refer to them lest I should be supposed to acquiesce in every statement which I do not attempt to refute. Besides the various notices in the "Records of the Geological Survey," a long paper containing descriptions of some fossil plants from the Damuda series in the Raniganj coal field has appeared in the "Journal of the Asiatic Society of Bengal,"[3] and contains numerous statements of opinion as to the relations of the beds and of their flora. With these opinions, in several instances, I am unable to coincide.[4]

Reasons for publication of previous paper.—As much of the annoyance exhibited by Dr. Feistmantel at the publication of my former paper appears due to my having written it before waiting till he had stated his views at greater length, and specially at my remarks appearing in the same fasciculus as his own, and as he has called attention to this circumstance in the "Geological Magazine,"[5] and in the "Neues Jahrbuch,"[6] I think I am justified in explaining my reasons for acting as I did. Mr. Medlicott, the Superintendent of the Survey, left me

[1] Leonhard und Geinitz, Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, 1877, p. 147.

[2] Dec. II, vol. III., p. 481.

[3] J. A. S. B. 1876, pt. 2, p. 329.

[4] There are also several remarks referring to members of the Geological Survey, and especially to Dr. Oldham, which are neither accurate nor just. See, p. 332, the paragraph commencing "But the fossils"—and p. 373, the fourth paragraph from the top of the page.

[5] l. c., p. 491.

[6] l. c., p. 148.

in charge of his office for three months, in July, August and September, 1876, and one of the duties entrusted to me was to edit the number of the "Records" for August. One paper by Dr. Feistmantel, "On the Age of some Fossil Floras in India," had appeared in the previous number of the "Records," and a second was left with me in manuscript. It appeared to me that both these papers were to some extent deficient; that whilst numerous circumstances were stated in favour of the writer's views, some important conflicting evidence was omitted, and that previous observers were treated in some cases not quite fairly. The opinions put forward as to the age of the rocks (and it should be remembered that, in Dr. Feistmantel's two first papers especially, the term "age" appears to be used in a distinctly chronological sense) seemed to me to be much more positive than was justified, even by the evidence adduced, and altogether I thought that if Dr. Feistmantel's remarks were published, it was only right to point out that there was another side to the argument. I thought, and still think, that Dr. Feistmantel would have consulted his own reputation and the interests of the Survey by abstaining from publication until he had given more study to the subject, and until he had more thoroughly mastered the language in which he wrote; but as I was only in temporary charge of the Survey publications, I did not feel justified in refusing to print the paper which had been left with me. I had, therefore, the choice of two courses to pursue: I might as editor have appended a running commentary of footnotes, calling attention to the points in which Dr. Feistmantel's opinions and statements differed from those of other observers, or I might have written a separate paper, explaining the data on which I felt obliged to dissent from Dr. Feistmantel's views. The first course is one which I have personally experienced more than once, and which I have always thought an unfair advantage taken by an editor; I consequently adopted the latter alternative as fairer and more courteous. I printed my remarks in the same number as Dr. Feistmantel's, first, because it appeared to me unjust to others to allow Dr. Feistmantel's statements to appear without comment; secondly, in order to have the advantage of correcting the proofs myself, as it was probable that I should not be in Calcutta when the next number of the "Records" was due. So far as I am able to judge, there was not a single line in my paper to which any objection could be taken on the score of courtesy and fairness, nor can I see that there is any cause for the annoyance which Dr. Feistmantel has since shown. Not only, so far as I can judge, was I perfectly justified in pointing out that there were several omissions in his paper, but it was to some extent a matter of duty to my colleagues to do so, and I endeavoured to accomplish this task without giving Dr. Feistmantel any occasion to suppose that he was harshly treated, or that I underrated the value of his observations. I can only regret having failed in my intentions, and that his reply compels me to call attention to matters I would willingly have forgotten.

Arrangement of present paper.—I proceed to the consideration of Dr. Feistmantel's various papers in the "Records of the Geological Survey," and especially to that which appeared in the fourth, or November, number for 1876. The course I propose to adopt is first to call attention to a few points on which I differ from the writer, or on which I think his remarks are liable to cause error, and then, taking the various groups of the Gondwána system from top to bottom, to

enquire how far Dr. Feistmantel's published views are consistent with facts, and to notice in each case his objections to my arguments. I should perhaps commence by saying that my first objection to Dr. Feistmantel's writing from beginning to end is that he repeatedly omits to state the whole of the facts; he brings forward just so much of the evidence as is in favour of his own views, and ignores the remainder. Of this I shall have occasion to give several instances. I quite believe this to be unconscious and unintentional on Dr. Feistmantel's part, but it tends to invalidate his arguments so seriously, that it is impossible to leave it unnoticed, and it has this most serious disadvantage that, as most of his papers are upon a somewhat abstruse subject, it is almost impossible in general to tell what points have been omitted.

The palæontological contradiction.—On p. 115[1] Dr. Feistmantel points out that on p. 29 he had fully noticed as a palæontological contradiction the discrepancy between the fauna and flora of the Kach group—that is, the Umia group of Dr. Stoliczka. This is correct, and I ought, perhaps, in my paper to have noticed it. Unfortunately, however, any one turning to Dr. Feistmantel's paper to learn his views as to the "age" of the Cutch (Kach or Kachh) beds would assuredly consult pp. 33, 34, where a summary of the conclusions is given. These conclusions appeared to me misleading in two respects: they represented the various localities from which plant-remains had been obtained in Cutch as belonging to two distinct horizons, and the only palæontological contradiction was said to be that plants indicating "generally an age as old as the Bathonian or Bath oolite, and some of them a still older horizon" were from higher beds than the ammonite fauna, which is "not older than Bathonian." I was, I think, fully justified in pointing out that the contradiction was much greater than would be supposed from Dr. Feistmantel's remark.

"*Premature conclusions.*"—At page 117 Dr. Feistmantel writes—

"I would next notice some points relating to the lower Gondwána groups upon which Mr. Blanford's conclusions were rather premature. It will appear (*a*) . . . . . (*b*) that the affinities of our Damuda flora with that of the mesozoic epoch and especially of the triassic formation are overwhelming, and that the arguments for this conclusion are not derived from three species discovered only last year."

A reference to vol. ix, p. 82, will show that this is not a correct representation of my language. I said "main arguments," and by divorcing the phrase from its context, the expression is made to take a very different aspect from that intended. All I wished to point out (*l. c.*) was, that although Dr. Feistmantel might be justified in considering the Damuda flora as triassic, his predecessors, who were ignorant of some of the facts since discovered, should not be blamed, as he had by implication blamed them,[2] for coming to a different conclusion. The only known connection of any importance between the Damuda flora and the European triassic flora, previous to the discovery of the three Karharbári

[1] Rec. G. S. I., vol. IX, pt. 4.

[2] See, for instance, Rec. G. S. I., vol. IX, p. 68. "It has been, and will perhaps yet be, endeavoured to show that the Indian Damuda series are of palæozoic age, but I do not see where is the proof, as the palæontological results, *the only possible proofs*, indicate *lower mesozoic*, &c." The italics are in the original.

plants belonging to *Voltzia*, *Albertia* and *Neuropteris* was in the occurrence in both of allied forms of *Schizoneura*. In Dr. Feistmantel's own conclusions (*l. c.* p. 77) the only Damuda species said to be triassic were *Schizoneura Gondwanensis*, *Neuropteris valida*, *Voltzia acutifolia*, "and perhaps *Albertia speciosa*," and I was, therefore, I think, not "premature" in concluding that Dr. Feistmantel's "main arguments" for the triassic age of the Damudas, were derived from the three last species, since the occurrence of the *Schizoneura* alone would scarcely have sufficed to indicate the age of the beds.

The differences between the floras of the upper and lower Gondwánas may not be quite so absolute as I thought that they were, but still the difference is very great. The question as to the "analogy with the flora of the lower coal strata in Australia" I will deal with hereafter.

The case of Macrotæniopteris.—On p. 118, in order to show that the Damuda (lower Gondwána) formation is closely allied to the upper Gondwána Rájmaháls, Dr. Feistmantel thus insists on the resemblance between certain forms of *Macrotæniopteris* found in the two series, and the distinction between them and the European carboniferous forms; in this instance the object is to shew that the Damudas are mesozoic—

"There are amongst the *Tæniopteridæ* two forms which are very near to some from the Rájmahál Hills, *Macrotæniopteris danæoides* being very near to *M. lata*, O. M. var. *musæfolia* . . . . "Of course it may be said again that these are genera of wide range, but yet the species are distinct; so is the *Macrotæniopteris lata* and *danæoides* well distinct from *Tæniopteris abnormis*[1] or *Germani* or *multinervis* in the carboniferous . . ."

It should be noticed that in the above extract, in order to emphasize the distinction between *Tæniopteris danæoides* and the European palæozoic species, the former is placed in the genus or subgenus *Macrotæniopteris*, whilst *T. abnormis* is classed with *T. Germani* in *Tæniopteris* itself.

A few pages farther however, (p. 128,) in what is virtually a distinct paper, instead of proving the Damudas high in the series, the object is to show that the upper Gondwánas are low down. The relations between the various species of *Macrotæniopteris* are again discussed, but with a slight difference. Not a word is said about the Damuda species, but Dr. Sterzel's notice of the close relationship between the Rájmahál species and *Tæniopteris abnormis* is quoted with approval—

"Dr. Sterzel says about these species (*M. lata*, *M. musæfolia*, and *M. Morrisi*) so closely allied with *Tænopt. abnormis*, Gutb., that there is scarcely any difference, and only the formation separates them. For me it is a great satisfaction to see forms, which I have declared to be liassic, so nearly related with a permian one."

Contrast this with the last extract, in which *M. lata* was said to be "well distinct" from *Tæniopteris abnormis*. But this is not all; farther on, at p. 137, a new *Macrotæniopteris* from the Damudas is described and shown to be intermediate in characters between the Rájmahál *M. lata* and the permian *M. abnormis*, and this piece of evidence is again brought in to prove the Damudas triassic.

"Our species holds a middle place between the permian *Tæniopt.* (*Macrotæniopt.*) *abnormis*, Gutb., and the three species of *Macrotæniopteris* from the Rájmahál Hills, and we have, therefore, in our triassic beds, between the permian and jurassic, a *Macrotæniopteris*."

[1] Subsequently said to be permian.

Yet again p. 142, in a description of new fossils from the Damuda (Raniganj) group, *Macrotæniopteris danæoides* is mentioned once more. Here, again, the object being to prove the Damudas mesozoic, *Tæniopteris abnormis* and its affinities are ignored, the resemblance between *T. danæoides* and the Rájmahál forms is again insisted upon, and the old arguments repeated. All the specimens are said to "have a very mesozoic aspect and strikingly resemble certain specimens from the lias (Keuper?) in the Alps."

I admit that this matter is comparatively of trivial importance, but still it is, I think, only right to call attention to it, because it is a typical and characteristic example of what I cannot but consider a radical error throughout Dr. Feistmantel's arguments. The whole of the facts, so far as I know, are stated in one place or another, but the mesozoic or the palæozoic relations of *Macrotæniopteris* are insisted upon, according as the one or the other is in favour of the writer's arguments at the moment.

Criticism of one of Dr. Feistmantel's sentences.—To illustrate the peculiar form of argument further, I will take for criticism a single sentence. Dr. Feistmantel first points out that Dr. Oldham endeavoured to show that the Damuda flora was palæozoic, that this view had been questioned by Sir C. Bunbury, and that subsequent collections afforded "unmistakable evidence" in favour of the mesozoic[1] and, in the writer's opinion, triassic age. He proceeds—

"Already in the old collections from Raniganj there were proofs enough. There were *Schizoneura* very frequent, there were one or two *Sagenopteris*, Presl., *Glossopteris*, different from those in Australia. From Kámthi there were specimens of *Tæniopteris* (*Macrotæniopteris* and *Angiopteridium*) of distinct real *Phyllotheca*, like that in the oolites in Italy; there were again a quite different *Glossopteris* from those in Australia, different not only by the shape of the leaf, but especially by the fructification." [2]

Now, so far as the old collections went, the only Damuda specimens of *Schizoneura* [3] which had been determined were from some of the highest beds in the Raniganj group at the top of the Damuda series: the form is locally abundant it is true, but, to the best of our knowledge some years ago, it was only found in the position I have stated. The *Sagenopteris* may be mesozoic, but the quotation of "*Glossopteris* different from those in Australia," is certainly no argument in favour of the mesozoic and triassic age of the Damudas. In the first place, it is only since Schimper's work appeared in 1869 that the species of *Glossopteris* have been distinguished; Dr. Oldham thought differently,[4] and be it remembered Dr. Feistmantel is in this paragraph imputing blame to Dr. Oldham

[1] l. c., p. 119.

[2] I, of course, copy these extracts as they are printed.

[3] In several papers, and especially in the "Geological Magazine," 1876, p. 488, and "Neues Jahrbuch," 1877, p. 155, Dr. Feistmantel writes of *Schizoneura* as though it were excessively common in the Damuda formation. This is, I think, a mistake. *Schizoneura* abounds in one or two beds in the Raniganj field amongst the very highest Damuda (Raniganj) strata, and a large number of specimens were collected from these beds, so that the plant is peculiarly well represented in the Museum, but so far as my own experience goes, I have only found *Schizoneura* leaves in, I think, two localities in the Raniganj field. The stems may have been found elsewhere, but they are far less common than *Vertebraria* and *Glossopteris*.

[4] Mem. G. S. I., Vol. II, p. 328.

on the score of the knowledge which existed in 1860-61,[1] not that available in 1876, but even supposing that the forms are distinct, the presence of *Glossopteris* different from those in Australia is no evidence either for or against the age of the Damudas being mesozoic or palæozoic.

The genus *Tæniopteris* (*Macrotæniopteris* and *Angiopteridium*) from Kámthi is the next proof. Now, when Dr. Oldham wrote, the genus *Tæniopteris* had not, to the best of my knowledge, been divided into subgenera, and therefore the relations of the genus as a whole were to be considered. But the genus is palæozoic as well as mesozoic, and Dr. Feistmantel himself admits, p. 137, the affinity between the Kámthi species and the permian one. Moreover, the specimens of *Macrotæniopteris*, if collected by Mr. Fedden, as Dr. Feistmantel states, were not amongst the old collections, for Mr Fedden first went to Kámthi in 1866, whilst Dr. Oldham's last paper was published in 1861.

Then, amongst the Kámthi fossils there was "distinct real *Phyllotheca*, like that in the oolites in Italy." No mention is here made of the connexion with the Australian *Phyllotheca*, admitted by every one to be just as closely allied to the Indian forms as the Italian are. This is far from the only instance in which this important alliance is left entirely unmentioned, although it is, of course, noticed elsewhere. As I shall show presently, there is good evidence that the Australian *Phyllotheca* occurs in undisputed carboniferous beds.

Lastly, the "quite different *Glossopteris* from those in Australia, different not only by the shape of the leaf, but especially by the fructification," is again urged as proof of the Damudas being mesozoic I have already noticed this argument, supposing Dr. Feistmantel to be correct in his facts; but is he correct? It will be seen that he admits of no doubt or question; the distinction in shape of leaf and fructification is asserted as a well-known fact, and from the context must be supposed to have been a fact sufficiently clear some fifteen or sixteen years ago Some quotations from Sir C Bunbury's paper on the flora of the Kámthi beds of Nagpur will serve to show how far the distinction was admitted as valid. Speaking of *G. Browniana* var. *Indica*, he says —[2]

"On comparing this Indian *Glossopteris* with the common Australian *G. Browniana*, allowing for the apparent differences produced by the nature of the stone, and the state of preservation of the specimens, I can find no satisfactory specific distinction; the venation is essentially the same . . . The general form varies considerably in the Australian specimens, and is often quite as narrow as in those from Nagpur; the apex also varies in the Australian plant, from very obtuse and even *retuse*, to rather acute, though I admit that it is never, in the specimens I have seen, as acute as in the Indian. I have seen no trace of fructification in Australian specimens, nor is any mentioned by McCoy; on the other hand, I am unacquainted with the rhizoma of the Indian *Glossopteris*. In the absence of these important points of comparison, we cannot feel certain of the specific agreement of the two."

In another place Sir C. Bunbury writes thus[3]:—

"Another and very striking characteristic of this Nagpur fossil flora is its close analogy with that of the coal formation of Australia. The prevailing plant in each of the deposits is a *Glossop-*

[1] 1865 according to Dr. Feistmantel, Rec. G. S. I., Vol. IX, p. 118, but he is in error, as the paper referred to is dated 1st June 1861, and appeared in the first part of Volume III. of the "Memoirs," published in 1861. Dr. Oldham's first paper, too, was published in 1860, not in 1861.

[2] Q. J. G. S., Vol. XVII, 1861, p. 328.

[3] l. c., p 342.

tetis, and it appears (as far as we can judge in the present state of our knowledge) to be actually the very same species in both?"

The above extracts relate solely to *G. Browniana* var. *Indica*, but the typical form of *G. Browniana*,—identical in shape of frond with the Australian species or variety,—was also recognised by Sir C. Bunbury amongst the Nagpur fossil plants.[1] Surely this fact ought to have been mentioned.

Again, as regards the fructification. As is shown above, Sir C. Bunbury (writing in 1861, the year in which Dr. Oldham's last paper was published) had no information as to the fructification of the Australian form. The only information since obtained, as far as I know, is that published by Mr. Carruthers in 1872.[2] He says, speaking of some specimens from Queensland—

"*Glossopteris Browniana* has been so frequently described and figured, that I find nothing additional worth recording from an examination of Mr. Daintree's specimens, unless it be that one shews some indications of fruit in the form of linear sori running along the veins and occupying a position somewhat nearer to the margin of the frond than to the midrib."

The fructification in the commoner Nagpur form of *Glossopteris* (*G. Indica*, not *G. Browniana*) which is figured in Sir C. Bunbury's paper,[3] is of course quite different. But is the evidence of "indications of fruit," observed only in one specimen amongst the numerous fronds of *Glossopteris Browniana* which have been examined, sufficient to justify Dr. Feistmantel's confident assertion that the Kámthi *Glossopteris* differs from "those in Australia" "especially by the fructification?" and why is the existence at Kámthi of *Glossopteris Browniana* identical with the Australian form left unnoticed? and is it fair to quote information first published in 1872, in order to show that a writer in 1861 was guilty of ignorance for not being aware of such facts?

I have criticised this passage at great length in order to show how very much Dr. Feistmantel's statements and arguments are open to question. The sentence I have taken is by no means exceptional, but it is of course impossible to go through the whole paper in the same way.

Proof of mesozoic age.—Still, before quitting this question of evidence, I may perhaps as well deal at once with Dr. Feistmantel's views of what constitutes "proofs of mesozoic age." Mr. Wood-Mason[4] is said to have brought a suite of fossils affording such proofs. Amongst the forms cited are *Vertebraria* and *Alethopteris Lindleyana*. In another place Dr. Feistmantel writes[5]—

"The Damuda flora exhibits itself quite decidedly as mesozoic and most naturally of triassic age, as out of thirty-one species known at present, there are nineteen distinctly mesozoic forms."

Or again[6]—

"The mesozoic (epoch) is marked by the following peculiar genera (of *Equisetaceæ*).

"*Schizoneura*, Sissimp.[7]	*Sphenophyllum*, a peculiar form.
Phyllotheca, Bgt.	*Vertebraria*, &c."

Is this not a case of *petitio principii?* One of the questions in dispute is whether the age of the beds in Australia, in which *Vertebraria* occurs, is palæozoic

[1] l. c., p. 329.
[2] Q. J. G. S. 1872, Vol. XXVIII, p 354.
[3] l. c., Pl. VIII, fig. 1, 4.
[4] Rec. G. S. I., IX, p. 119.
[5] l. c., p. 121.
[6] J. A. S. B., Vol. XLV, 1876, pt. 2, p. 337.
[7] This is, of course, a misprint.

or mesozoic, and as the genus is unknown elsewhere, except in the Indian rocks, it can only be a mesozoic form because of its occurrence in those Australian beds. Now, those beds are held to be of palæozoic age by authorities whose opinion is certainly entitled to some respect, and, as I shall show presently, the evidence in favour of this view has been, I think, greatly underrated by Dr. Feistmantel. The same argument applies to *Phyllotheca* with even greater force, because this genus is stated by Mr. Clarke[1] to occur in the *Glossopteris* beds interstratified with marine carboniferous rocks, and if it be replied that Mr. Clarke may have been mistaken in his identification, and that there were no specimens of *Phyllotheca* in the imperfect collection from the lower Australian coal beds examined by Dr. Feistmantel himself, I would call attention to a letter from Professor McCoy to Mr. Daintree printed in the "Quarterly Journal of the Geological Society" for 1867.[2] Professor McCoy is surely a competent observer, and as he is, and has always been, the most energetic advocate of a mesozoic age for the Australian plant-bearing rocks, his evidence may fairly be accepted in this case. He identified certain plants from Queensland as *Glossopteris Browniana* and *Phyllotheca Australis*, and although it is not stated that the *Phyllotheca* occurred with the *Glossopteris*, I do not think any one can read the paper without understanding that the association of these two plants in the same beds is distinctly implied, and not only is it said that the *Glossopteris* occurs in beds below those containing carboniferous fossils, but Mr. Clarke expressly states "no *Glossopteris* has been found in Victoria, Queensland, Western Australia, or in New South Wales, except in association with beds containing fossils of palæozoic age,"[3] and this same statement has since been repeated even more emphatically by Mr. Daintree.[4] Again, in another paper,[5] Mr. Clarke mentions that a plant found by Leichhardt in a bed "in the midst of, and far below," others with lower carboniferous animal forms, was afterwards found to be a *Phyllotheca*. In the face of all this evidence is it correct to write of the genus *Phyllotheca* as a proof of mesozoic age, or to quote it as a type peculiar to mesozoic strata?[6]

As regards *Sphenophyllum*, the distinctions between the Damuda *S. speciosum* (or *S. trizygia*) and the palæozoic species may be of great importance, but still the fact remains that, except in Damuda rocks, the genus is only known from palæozoic strata. Surely Dr. Feistmantel does not mean to argue that the peculiar form is mesozoic because it occurs in Damuda rocks, and Damuda rocks are mesozoic because they contain the peculiar form of *Sphenophyllum*? Yet in what other manner can the genus be quoted as evidence of mesozoic age?

[1] "Mines and Mineral Statistics," section No. 1, opposite p. 206 and p. 166, "The Greta beds are not the uppermost with marine fossils, but beds with them lie farther to the east, in which *Phyllotheca* has occurred at Harper's Hill." See also the notes by Mr. Wilkinson, l. c., p. 132. These are quoted in p. 130 of this paper.

[2] Vol. XXIII, p. 11.

[3] Q. J. G. S., 1866, Vol. XXIII, p. 10.

[4] Q. J. G. S., 1872, Vol. XXVIII, p. 288

[5] Q. J. G. S., 1861, Vol. XVII, p. 362.

[6] See also J. A. S. B 1876, Vol. XLV, pt. 2, p. 317.

The nineteen distinctly mesozoic Damuda forms.—I have disposed of two out of the nineteen "distinctly mesozoic forms" in the Damudas, *Sphenophyllum speciosum* or *trizygia* apparently not being included in the number.[1] The beds containing *Neuropteris valida*, *Voltzia*, *Albertia*, and *Glossozamites*, as I will show presently, must be separated from the true Damudas. The other mesozoic Damuda types comprise *Alethopteris Lindleyana*, allied, it is true, to some European mesozoic forms, but equally close to *A. Australis* from the Newcastle beds of Australia or their representatives in Tasmania; *Macrotæniopteris*, two species, the affinities of which have already been shown not to be exclusively mesozoic: and *Gangamiopteris*, three species, classed as mesozoic on account of the occurrence of the genus in certain beds in Victoria (Australia), the assumption as to the age of which beds depends entirely upon the same evidence—fossil plants—as has been shown to be fallacious in New South Wales. One species of *Gangamopteris*, too, is common to the beds of Victoria, and to those of Newcastle (New South Wales), always classed by Mr. Clarke as palæozoic. It is quite possible that the Victoria beds may be mesozoic,[2] but there is no evidence that they are newer than the Hawkesbury and Wyanamatta beds of New South Wales, and the animal remains in the latter exhibit palæozoic affinities. It would be quite as just and reasonable to argue on this evidence that the Victoria beds are palæozoic as it is to assume, as Dr. Feistmantel does, that the Australian strata containing *Vertebraria* and *Phyllotheca* are mesozoic. It is evident that out of the "nineteen distinctly mesozoic forms" only seven, *viz.*, *Schizoneura Gondwanensis*, *Actinopteris Bengalensis*, *Angiopteridium* sp., three species of *Sagenopteris*, and one of *Noeggerathia* have, when the Karharbári plants are omitted, any claim to the title, and of these, none, except the *Schizoneura*, can be said to be sufficiently known for their affinities to be clearly ascertained, nor, with the same exception, do any of the plants named belong to characteristic forms. *Actinopteris* is a common living genus, *Sagenopteris* is close to *Glossopteris*, and although it is highly probable that the European and American palæozoic *Noeggerathiæ* differ from the Damuda types, the latter are allied to Australian forms, and none are sufficiently well understood for their relations to be unmistakable. I fully grant that in arguing thus I am raising minor objections, but my object is to point out that the evidence is strained by Dr. Feistmantel, and that any one arguing on the other side, and using the same style of reasoning, could produce at least as good proof in favour of coming to a diametrically opposite conclusion.

The asserted absence of animals in upper Australian coal-measures.—These remarks tend to become so lengthy, that I can only notice one or two other points before proceeding to the second part of my subject. Dr. Feistmantel's classification of the Australian coal-bearing rocks[3] into Upper and Lower differs entirely from that adopted by Mr. Clarke and other Australian geologists, and the remark appended to the whole of the upper beds, including the Wyanamatta, Hawkes-

[1] Rec. G. S. I., Vol. IX, p. 121.
[2] See p. 142.
[3] Rec. G. S. I., Vol. IX, p. 123. The subject will be found more fully treated further on, p. 137

bury, and Newcastle groups,[1] "No animals," is of course a mistake, as is the statement on the next page, that the rocks of Bowenfels and Newcastle contain "*no animal fossils*" (the italics are in the original). The fact that the animal fossils are fishes with palæozoic affinities is omitted, and as it is impossible to suppose that Dr. Feistmantel was ignorant of this circumstance, the omission affords a good instance of his habit, to which I have already referred, of suppressing all evidence opposed to his views, but I have no doubt the assertion that "no animals are found in the beds" is an oversight, and that the author's intention was to write no *marine* animals.

In the table, however, at p. 125, illustrating the relations between the beds in Europe, India, and Australia, Dr. Feistmantel writes, under the heading of Coal-measures in Australia "(a)—*Upper coal-measures . . . . Flora only.*" It is impossible to acquit Dr. Feistmantel of a mistake in a matter of fact in this case.

It is only to be regretted that in this, as in numerous other instances, Dr. Feistmantel has not been more careful in writing his papers and in reading the proofs, since mistakes of this kind are certain to mislead readers who depend upon the writer for their information on a little-known subject, and who are just as seriously deceived by an unintentional slip as by a deliberate misstatement. The error is due to oversight of course, but mistakes in such matters tend to diminish the confidence we should otherwise feel in the writer's accuracy.

Zeugophyllites and Schizoneura.—In a footnote, p 119, Dr. Feistmantel points out that neither the Australian *Zeugophyllites* nor *Noeggerathia*, is a *Schizoneura*, referring at the same time to my having suggested that the Australian *Noeggerathia* might be a *Schizoneura*. In other papers the same matter is referred to and in much stronger language.[2] The mistake is entirely Dr. Feistmantel's own. In his original paper in the "Records"[3] he wrote thus:—

"The fossils described as *Zeugophyllites*, Brgt from India by Brogniart (Prodrome, 121-175) and subsequently by Strzelecki ('Physical Description of New South Wales, &c.') seem to belong also to *Schizoneura*."

And the same fossil is alternately called *Noeggerathia* and *Zeugophyllites* by different Australian geologists.[4] I am quite aware that Dr. Feistmantel, in a footnote to his paper[5] on Raniganj plants, written after my paper was published, asserts that the words "according to Dr. Oldham" have been omitted at the close of the above extract; but Dr. Feistmantel is responsible for the omission, not I. The correction, too, should have been in the "Records," and not in a footnote in the

[1] The occurrence of a fish in the Wyanamatta and Hawkesbury beds is, in fact, mentioned in the next page. The palæozoic affinities of the species are, however, not noticed.

[2] J. A. S. B., Vol. XLV, 1876, pt. 2, p. 345. "It is also incorrect to consider, as Mr. W. T. Blanford has done, the Australian *Noeggerathia* as ? *Schizoneura*, the two latter genera being quite as distinct as the two former (*Schizoneura* and *Zeugopyllites*) are from one another, and I think certainly that Mr. W. B. Clarke would be able to distinguish a *Noeggerathia* from a *Schizoneura*, and *vice versâ*."

[3] Vol. IX, p. 69.

[4] Q. J. G. S., 1861, pp. 359, 360. In the latter page Mr. Clarke himself speaks of *Noeggerathia* (or *Zeugophyllites*).

[5] J. A. S. B., Vol. XLV, 1876, pt. 2, p. 346.

middle of a long paper, which nine-tenths of the readers of the "Records" in all probability never heard of. As the matter stands, Dr. Feistmantel charges me with his own blunder, precisely as he did in the matter of *Gangamopteris*,[1] although he subsequently apologized for his remarks in the latter case.[2]

PART II.

The age of the Gondwána groups.

I.—UMIA *(Kach)* AND JABALPUR.—I proceed to answer Dr. Feistmantel's notes on the age of some of the Gondwána groups, and will commence, as he has done,[3] with the uppermost, the Umia beds of Cutch (Kach or Kachh.) It is agreed that the *Cephalopoda* of these beds have uppermost jurassic affinities, and that the plants, which are in strata overlying those containing the *Cephalopoda*, are related to English lower oolitic (middle jurassic) forms, but it is urged by Dr. Feistmantel, in opposition to Dr. Waagen,[4] that "it is very possible that the full examination of the *fauna* may modify the stratigraphical relations as deduced from the *Cephalopoda*," and again,[5] "I may here remark that from a cursory inspection I have made of the Kach collections, I do not think they will bear out the inferences based upon the *Cephalopoda* as to the Tithonian horizon of the upper members of the series."

It is as well to quote the first passage further. Dr. Feistmantel says—

"There are certainly some mollusca that are generally of older age than Portlandian, passing into the higher beds of Kach.

"*a.*—I may mention only from the Umia group (which contains the Portlandian *Cephalopoda*) the very frequent occurrence of—

"*Goniomya V-scripta*, which mostly occurs in middle jurassic beds in Europe.

"*Astarte major*, Sow., very near with *Astarte maxima*, Om., from middle Jura in Germany.

"A *Trigonia* near *Trigonia vau*, Sharpe, from jurassic beds on the Sunday river in South Africa.

"A *Goniomya* scarcely different from *Goniomya inflata* Ag., a middle jurassic form—also related with *Goniomya rhombifera*, Goldf. from liassic strata.

"A *Trigonia* very near to *T. Herzogii*, Hausm, from Enon on the Sunday river in South Africa.

"Some *Trigoniæ* allied with *Tr. ventricosa* in South Africa.

"A portion of the lower jaw junction[6] of a *Plesiosaurus* which has mostly allied forms in the English lias—found near Borooria in the Umia group."

I naturally feel some hesitation in disputing the opinions of the Palæontologist of the Geological Survey on palæontological questions, and especially on so very elementary a subject as the value of palæontological evidence, but I must confess that, supposing even that the above were a correct statement of the affinities of the fossils named (and I shall show that it is not); supposing

[1] Rec. G. S. I., Vol. IX, p. 122.

[2] Rec. G. S. I., X, p. 76.

[3] Rec. G. S. I., Vol. IX, p. 116.

[4] Pal. Ind., Ser. IX, Vol. I, pp. 225, 233;

[5] Rec. G. S. I., Vol. IX, p. 135.

[6] Distal portion or symphysis of the mandible is meant, not, as might perhaps be supposed, the condyle.

that no relations to forms in higher beds have been omitted, and that the evidence is in no case one-sided, all I can say is that Dr. Feistmantel's ideas upon palæontological evidence differ widely from what I have always supposed to be the accepted views of geologists in general. I may be in error, but I should have thought that in upper jurassic strata some species would certainly be found closely allied to middle and lower jurassic forms, and that a few might be identical. I notice that all the species mentioned except the *Plesiosaurus* consist of Lamellibranchiate bivalves (*Pelecypoda*), and that Dr. Waagen, whose opinion on the subject is probably not given without reason, has especially referred[1] to alliances between some of the Umia *Pelecypoda* and those of the Portland beds, and I have always been under the impression that the selection of a few forms from amongst a large number as evidence of the affinities of a fauna is liable to mislead, and that the true relations are only to be determined by a comparison of the whole. From the Portland group itself, there would, I think, be no difficulty in selecting half a dozen species of mollusca allied to middle or lower jurassic forms. Perhaps the value of the evidence adduced, assuming it to be correct, may be best shown by taking a parallel case.

The cretaceous beds of Southern India comprise a group representative of the upper cretaceous rocks (white chalk with flints or Senonian) in Europe. In this Southern Indian group, that of Arialúr, amongst other fossils, the following occur[2]—

Nautilus Bouchardianus, found in Europe in the		gault (middle cretaceous),
N. Clementinus	" "	gault,
Ammonites Velledæ	" "	neocomian and middle cretaceous,
A. Deccanensis, *A. Arrialoorensis*	belonging to the group of *macrocephali* and allied to European jurassic forms,	
Fulguraria elongata (*Voluta elongata*, D'Orb.)	found in European	middle cretaceous beds,
Cerithium trimonile	"	gault,
Euspira rotundata (*Turbo rotundatus*, Sow.)	"	upper greensand,
Ziziphinus Geinitzanus	"	Hippuritic limestone (Turonian),

besides *Ammonites Gardeni* and *Euchrysalis gigantea*, found also in South African beds supposed to be of Cenomanian (upper greensand) age. These identifications, be it recollected, with the exception of the two *macrocephali* ammonites, are specific; they are not mere cases of related forms, as in the fauna of the Umia beds, and the list might be considerably increased if every form allied to European middle or lower cretaceous species were quoted. Yet there cannot be the slightest doubt that the fauna of the Arialúr beds is typically upper cretaceous, taken as a whole. It is, I think, needless to adduce further evidence to show of how little value the argument against the upper jurassic age of the Umia beds would be, even if it were correct.

But then comes the question—How far is this evidence correct? Three of the six mollusca mentioned are *Trigoniæ* allied to the South African forms *Tr. vau*, *Tr. Herzogi*, and *Tr. ventricosa*, and Dr. Feistmantel, quite correctly I believe, points out[3]

[1] l. c., p. 225.
[2] Pal. Ind., Ser. I, III, V.
[3] Rec. G. S. I., Vol. IX, p. 116.

that "there is a great affinity of some of the fossils in the uppermost beds of Kach with forms from the South African strata on the Sundays and Zwartkop rivers." He proceeds to show that these South African fossils were at first supposed by Krauss to be lower cretaceous; subsequently they were classed by Bain as liassic, and finally by Sharpe and Tate as of the same age as the great oolite of England (middle jurassic). Now, Dr. Feistmantel has, I think, overlooked some later information than that quoted by him. Tate[1] is the last writer noticed, and he, like all previous observers, supposed the upper portion of the Uitenhage formation, from which the jurassic fossils described came, to consist of a single group, although he noticed[2] the occurrence of two cretaceous forms, a *Hamites* and a peculiar *Crassatella* allied to a neocomian species.

In a paper "On some Points in South African Geology"[3] by Mr. G. W. Stow, published four years after the appearance of Mr. Tate's description of the fossils, it was shown that the jurassic beds belonging to the Uitenhage formation on the Zwartkops and Sundays rivers comprised several different groups distinguished by their fossils.[4] The most important section is the following on the lower Sundays river:—

POST-TERTIARY.

UPPER JURASSIC—

1. Few and small *Trigoniæ*.
2. Zone of *Trigonia ventricosa* and *Tr. vau*, with *Gervillia dentata*, *Exogyra imbricata*, &c.
3. Few *Hamites* and wood.
4. Zone of *Modiola* (*M. Baini*) and *Hamites*, *Belemnites* (*B. Africanus*), *Ancyloceras* (?), *Trigonia Goldfusi*, *Crassatella complicata*.

Strata hidden.

LOWER JURASSIC—[5]

5. *Astarte Herzogi*, *Trigonia Herzogi*, *Pleuromya lutraria*.

Before proceeding further, it is perhaps as well to notice that, of all the Umia species mentioned as having supposed middle or lower jurassic affinities, the most important is *Trigonia ventricosa*, because it and another *Trigonia*, *Tr. Smeei*, are amongst the commonest and most characteristic fossils of the group, and because both forms are also found on the eastern coast of India in beds associated with others containing upper Gondwána plant-fossils. *Tr. ventricosa* too, it should be remembered, is closely allied to the Indian middle cretaceous *Tr. tuberculifera*.[6]

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[1] Q. J. G. S. 1867, Vol. XXIII, pp. 139, 164, 169, &c.

[2] l. c., p. 165.

[3] Q. J. G. S. 1871, XXVII, p. 497.

[4] See especially l. c., fig. 3, opposite p. 500.

[5] The term 'lower' is probably merely intended to signify that the beds named are inferior in position at the locality. The age of these beds cannot well be earlier than lower oolitic, which is by many geologists classed as middle jurassic, lias being lower jurassic.

[6] Pal. Ind., Ser. VI, p. 315. In a footnote to the description of this shell, Dr. Stoliczka points out that although some of the fossils associated with *Tr. ventricosa*, and described, together with that species, as cretaceous by Krauss, are clearly jurassic, others appear to have cretaceous affinities. Dr. Stoliczka wrote in 1871, before Mr. Stow's paper appeared.

For the moment, it will be as well to attend to *Trigonia ventricosa* and *Tr. vau* alone. Both these shells were found elsewhere in the district near Port Elizabeth in beds supposed to be at a lower horizon, but they are there comparatively rare and isolated,[1] whereas in the uppermost bed on Sundays river they are so extremely abundant as to be characteristic. The next bed below the *Trigonia* zone is very important, because it is the only one containing *Hamites Africanus* and the lowest with *Crassatella complicata*, both forms with distinct cretaceous affinities,[2] but another species peculiar to the bed is *Belemnites Africanus*, a near ally of *B. Grantianus* (*B. Kunkotensis* of Waagen) one of the most typical fossils of the Katrol group of Cutch, and ranging into the bottom beds of the Umia group. At the same time amongst the remaining fossils in the *Modiola* and *Hamites* Zone on the Sundays river one is identified with *Trigonia Goldfusi*,[3] a lower oolite (middle jurassic) fossil, and *Modiola Baini* is also related to a great oolite species, but the *Modiolæ* and *Mytili* are by no means characteristic forms, and cretaceous or even later allies might easily be indicated. In another stratum on the Upper Sundays river,[4] together with *Modiola Baini* and apparently on the same horizon, *Ammonites subanceps* is found, and this form is but dubiously separable from *A. anceps* of the lower Chári beds in Cutch and Callovian of Europe. It is thus evident that there is too large a representation of middle jurassic fossils to justify the reference of the *Hamites* bed to neocomian, but still there can be no question of its occupying a very high jurassic horizon, and the zone of *Trigonia ventricosa* and *Tr. vau* is even higher.

Trigonia Herzogi, in the section on Lower Sundays river, was only found at a considerably lower horizon than *Tr. ventricosa*, but on Upper Sundays river it was found in a bed overlying the *Modiola* zone and apparently, according to Mr. Stow, as high in the series as the *Tr. ventricosa* band.

Gervilla dentata of the Hamite bed on Sundays river is apparently identical with a species found in the Umia group. If not identical, the forms are very closely allied.

A comparison of Mr. Lydekker's remarks[5] on the fragment of a *Plesiosaurus* mandible from the Umia beds, will show that Dr. Feistmantel overrates the importance of the occurrence. *Plesiosaurus* ranges from lias to cretaceous, and the occurrence of more numerous species in the former is due to the preservation of many specimens at one favoured locality. As the mandibles of the upper oolitic and cretaceous forms are not known, the fragment from the Umia beds was at first compared to a liassic species, but it subsequently proved to be distinct.

The specimens attributed to *Goniomya V.-scripta* I am unable to find in the Survey collections. It is possible that there may be some mistake about the identification, and I have reasons for believing that the fossils at first supposed

[1] l. c., p. 502.

[2] See Tate: Q. J. G. S., 1867, vol. XXIII, pp. 150, 160, 165.

[3] This species, however, in South Africa appears to pass up into beds of probably cretaceous age. Stow: l. c., pp. 513, 514.

[4] Stow: l. c., p. 503.

[5] Rec. G. S. I., vol. IX., p. 154; vol. X., p. 41.

by Dr. Feistmantel to represent the *Goniomya* belong to *Trigonia vau*. The only *Goniomya* I can discover certainly resembles *G. inflata*, but the specimens are not very good. This species and *Astarte major* are in fact, so far as I can see, the only forms mentioned by Dr. Feistmantel which really indicate an alliance between the Umia fauna and that of middle jurassic beds.

It is scarcely necessary to point out how very strongly the evidence of the *Trigoniæ* confirms Dr. Waagen's views of the upper jurassic affinities of the Umia group; as the *Cephalopoda* of the group are confined to the lowest beds, it is quite possible that the upper portion, containing the plants, may be of wealden or even neocomian age. The only marine fossil known to be found above the plant-beds is *Tr. Smeei* (I am not sure whether *Tr. ventricosa* accompanies it or not) and there is no reason why this species should not range into lower cretaceous. This position would quite accord with the circumstances of the Umia group being immediately succeeded by strata with upper neocomian *Cephalopoda*, if the former pass up into the latter. It is not, however, clear from Dr. Stoliczka's notes whether this is the case or not.

Of course all that has been said as to the impossibility of determining the horizon of beds from the affinities of a very small percentage of selected fossils is equally applicable to Dr. Feistmantel's remarks on the Katrol and Chári beds.[1] Is the occurrence of a single middle jurassic *Monotis* in the Katrol group, and of a liassic species of the same genus in the Chári beds of any weight when compared with the mass of evidence afforded by the cephalopod fauna?[2] In the sub-divisions of the Chári group alone there are thirty-nine *Cephalopoda*, either identical with European species, or so closely allied that Dr. Waagen, who is not addicted to uniting species, does not separate them. We are actually asked to doubt this evidence on the strength of a single species of *Monotis*. It would be as reasonable to suppose the Chári group cretaceous because it contains two *Terebratulæ*, which have been referred to the cretaceous species *T. sella* and *T. biplicata*.

Again as to *Parasuchus*, the identification of the Maleri flora with that of Jabalpur was hazardous, to say the least, but whether the identification was correct, or whether, as now appears probable, the Maleri beds are older than the Jabalpur group, either they are not triassic, or Dr. Feistmantel's own identification of them is wrong. Why then, in order to make out the Cutch beds older, does he write[3] of "*Parasuchus*; a vertebra of that Crocodilian fossil which is looked upon as Triassic, and which occurs frequently with the Jabalpur flora near Maleri, which latter is identical with our Kach flora." Mr. Lydekker[4] has since shewn that the generic identity of the Cutch and Maleri fossils is uncertain.

Before concluding these remarks on the Cutch beds there is one more point to which I have to take exception, and that is the classing together of the Umia

[1] Rec. G. S. I., vol. IX., p. 116.
[2] Pal. Ind., Ser., vol. IX, pp. 226-230.
[3] Rec. G. S. I., vol. IX., p. 116. See also Pal. Ind., Ser. II, pt. 2, p. 57.
[4] Rec. G. S. I., vol, X, p. 35.

and Katrol groups of Cutch, without, so far as I can see, any sufficient evidence being produced in justification of the change.

In the introduction[1] to the description of the flora of the Golapilli beds (Rájmahál) referring to *Trigonia ventricosa* and to its occurrence in some beds at Innaparazpilli near Coconada, Dr. Feistmantel writes, "The same form occurs in the upper beds (Umia and Katrol)," and a few lines further on, "As now the upper beds in Kach, with that *Trigonia*, are called *Umia* and *Katrol* (both being thus joined by the most common fossils), these *Trigonia* beds near Innaparazpili may be taken to represent both these groups in Kach." On the next page[2] the Sriparmatur and Ragavapuram beds are said to be overlaid by Katrol and Umia deposits, and in a table showing the supposed relations of various upper Gondwána groups, the higher beds in Cutch (Kach) are classed together as Umia-Katrol. There are, I may add, several points of correlation in this table which are, to say the least, open to question.

Trigonia ventricosa may be found in the Katrol group, although I can find no previous mention of its occurrence, but it is certainly not common, and it is misleading to say that the Umia and Katrol groups "are joined by the most common fossils." Altogether, forty-five species of *Cephalopoda* have been found in the two subdivisions of the Katrol group and ten in the Umia, and of these only one, *Belemnites Kunkotensis*, is common[3] to the two, another being indicated as doubtfully identical.[4] So far as I am aware, too, the characteristic bivalves of the Umia group do not occur in the Katrol beds. I think Dr. Feistmantel may have expressed himself ill, and that what he really means is that the plant-remains of the two groups are similar, but it is scarcely correct to speak of these as the most common fossils, for they are rarer than marine fossils in the Umia group, and in the whole Katrol subdivision they have hitherto only been detected in one locality.

KOTA-MALERI BEDS.—On these I have very little to say. They were at first classed by Dr. Feistmantel as Jabalpur beds[5] on account of the occurrence of two Jabalpur species of Conifers, *Palissya Jabalpurensis* and *Araucarites Cutchensis*, and a supposed lower portion was separated and considered equivalent to the Rájmahál group[6] on account of the occurrence of *Palissya conferta* and *Chirolepis Muensteri*. This view was adopted at first by Mr. Hughes and Mr. King on the evidence of the plants. It is instructive, and it affords an example of the risk of placing too much dependence on fossil-plants, to find that the discovery of additional species in the Kota-Maleri beds has shown that the rocks contain a mixture of

[1] Pal. Ind., Ser. II, pt. 3, p. 164.

[2] l. c., p. 165.

[3] Pal. Ind., Ser. IX, p. 4. At p. 232, however, Dr. Waagen says that not a single species passes from the Katrol into the Umia group. The doubtful identification is *B. claviger*.

[4] l. c., p. 7.

[5] Rec. G. S. I., Vol. IX, pp. 86, 134-135.

[6] Rec. G. S. I., l. c., Pal. Ind., Ser. II., pp. 57, 165, 190. See also Mr. King, Rec. G. S. I., Vol. X, p. 61, &c. Subsequently Dr. Feistmantel modified his statements about the absolute separation of the groups in the Gondwána region, Rec. G. S. I., X, p. 29, but the mischief was done.

Jabalpur and Rájmahál forms, and that the separation of the beds with Rájmahál fossils is untenable.

In two or three cases the reptilian fossils of the Kota-Maleri beds are quoted by Dr. Feistmantel as liassic. Thus, in one instance[1] he writes, "Remains of *Lepidotus* and of *Hyperodapedon* have also been found in the *Ceratodus* beds indicating the same liassic formation;" and again,[2] "In the Wardha field . . . the same flora (Jabalpur) is associated with liassic terrestrial animals." The only liassic forms are fish; the sole animal of probably terrestrial habits hitherto described[3] is *Hyperodapedon*, which in Europe is exclusively triassic, and the affinities of both *Parasuchus*[4] and *Ceratodus* are unmistakeably triassic. It is, in fact, the association of characteristically triassic types with equally marked liassic genera in the same group of rocks which adds so greatly to the interest of the Kota-Maleri beds,[5] and the circumstance that these remains are clearly insufficient to enable the geological age of the beds to be accurately determined shows how cautious we should be in attaching weight to the far less characteristic plant evidence.

RÁJMAHÁL GROUP.—In proceeding to the Rájmahál flora I should, perhaps, commence by saying that Dr. Feistmantel may possibly be correct in considering it liassic, but I think he fails to prove his case, and I cannot but believe that the emphatic assertion and re-assertion that the flora is liassic, on every page of the "Palæontologia Indica,"[6] from title to colophon, is a mistake. I think the arguments in favour of the flora of the Umia group of Cutch being middle jurassic are certainly stronger than the instances brought forward to prove the liassic affinities of the Rájmahâls, and yet[7] the apparent connexion in the first instance is misleading.

I shall not attempt to go into the question of the Rájmahál flóra in detail. I simply take Dr. Feistmantel's own data, as fully given in the "Palæontologia Indica,"[8] and I find that fifteen species are said to be closely allied to rhætic fossil

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[1] Rec. G. S. I., Vol. IX, p. 135.

[2] Pal. Ind., Ser. II, p. 56.

[3] Q. J. G S., Vol. XXV, 1869, p. 138. It may be thought that I am descending into trifling details, and that it is unfair to quote what may, after all, be misprints. I can only say that I am merely taking a few instances of mistakes almost at random, and I could give many more. Whether liassic is a misprint for triassic, or whether the mistake is due to carelessness, the effect is the same. I should probably have omitted the paragraph but for finding the following statement made by Dr. Feistmantel about the Kota-Maleri fossils in the last number of the "Palæontologia Indica" containing the description of the Jabalpur Flora, Ser. XI, pt. 2, p. 102-22, "We know, for instance, that *Hyperodapedon* in England is a Triassic Dinosaurian, and so is *Belodon* in Germany."

I regret having to call attention to such mistakes, but it is not fair to the other members of the Survey, who have been mercilessly criticised by Dr. Feistmantel, that errors like this should be left unnoticed. It must be remembered that Dr. Feistmantel has always had proofs of his papers, and consequently is fully responsible for any errors in them.

[4] Q. J. G. S., Vol. XXXI, 1875, p 430, &c.

[5] Rec. G. S. I., Vol. IX, p. 84.—Pal. Ind. Ser. IV, pt. 2. p. 17.

[6] Ser. II, pts. 2, 3; see also Rec. G. S. I., Vols. IX, X, *passim*.

[7] Rec. G. S. I., Vol. IX, p. 82.

[8] Ser. II, pp. 143, 187, &c.

plants and only three to liassic, two out of these three having equally close rhætic affinities. Omitting these two, the rhætic affinities of the Rájmahál flora are shewn to be in proportion to the liassic affinities as thirteen to one, or in other words, the connection with the European lias is only one-thirteenth of the affinity to the rhætic. Not a single identical species is known with certainty to occur in either case,[1] the only suggested identification, that of *Pterophyllum propinquum*, being, as Dr. Feistmantel himself notices, founded on a fragment too imperfect for accurate determination.

It is perfectly true that besides the liassic and rhætic forms, there are shown to be four or five Rájmahál species[2] related to middle jurassic (lower oolitic) plants, one being identical; and this argument, which is indicated, though not so clearly as could be desired, in the 4th paragraph on p. 160, is the only one of any value urged. At the bottom of the page, however, Dr. Feistmantel says, "We have, therefore, fossil plants which exhibit Liassic character, with some forms having their representatives in the Rhætic." Everywhere, on page after page, the liassic relations of the flora are insisted upon, and it is only when, turning from assertions to facts, the reader commences to examine the relations of the plants in detail, he finds liassic affinities are scarcely shewn to exist. Of the style of argument adopted, I will quote only one instance. On one page[3] the genus *Palissya* is said to be known only from rhætic strata; on the opposite page, near the bottom, is the following line, "CONIFERÆ. *Palissya indica*, Fstm., indicating lias."

The real fact, so far as I can judge from Dr. Feistmantel's data, is that the Rájmahál flora has very little similarity to any known fossil flora in Europe. There is a certain generic connexion with certain lower and middle mesozoic plants, but there is absolutely less similarity to the rather poor flora of the lias than there is to the rhætic or even to the oolitic flora. To label the flora as characteristically lias is, I think, a mistake, and will lead to error.

It is so difficult to hunt out anything through Dr. Feistmantel's multifarious notes and descriptions, of which I trust I may be pardoned for saying that the arrangement might be improved with advantage, that I may have overlooked some reference to the relations between the Rájmahál flora and that of the Uitenhage formation in South Africa, but I have not found any notice of this important fact.[4] The latter flora occurs in the Geelhoutboom beds or wood bed

[1] At p. 160 several liassic plants are enunciated, *Alethopteris Whitbyensis*, *Pecopteris Nebbensis*, *Thinnfeldia rhomboidalis*, &c., and are said to have near analogies in the Rájmahál group. In the "General table of the fossil flora of the Rájmahál group with relations and analogous forms in other formations," pp. 143–148, and at p. 155 in the list of characteristic plant-remains of the group and their age, it is shown in several instances that the affinities of the Rájmahál species with rhætic plants are closer than with the liassic forms subsequently mentioned.

[2] *Sphenopteris arguta*, *Pterophyllum fissum*, *Williamsonia* sp., *Araucarites macropterus* and perhaps *Hymenophyllites Bunburyanus*.

[3] Pal. Ind., Ser. II, p. 154.

[4] Tate: Q. J. G. S. 1867, Vol. XXIII, pp. 144, 169, &c. I think the connexion has been briefly noticed by Dr. Feistmantel in the "Neues Jahrbuch," but I am unable to find the passage.

series, which underlie the rocks with upper and middle jurassic fossils on Sundays and Zwartkops rivers, and overlie the Enon conglomerate at the base of the Uitenhage formation, to which succeeds in descending order the Karoo series, classed by Tate as triassic, but probably, in part at least, older. The following plants have been described[1] :—

FILICES.

Pecopteris Atherstonei } both nearly allied to *P* (*Alethopteris*)
P. Rubidgei } *Indica*, a Rájmahál form
P. Africana.
Asplenites (or *Pecopteris*) *lobata*, a Rájmahál species
Sphenopteris antipodum.
Cyclopteris Jenkinsiana.

CYCADACEÆ.

Palæozamia (Otozamites) recta.
P. (Podozamites) Morrisi.
P. Rubidgei.
P.? Africana.

CONIFERÆ

Arthrotaxites (Echinostrobus) Indicus ?[2] closely allied to a Rájmahál plant, if not identical.

LOWER GONDWÁNA.—PANCHET GROUP.—If the age of the Panchet group were determined by the plant fossils, there can be no question, on the strength of the evidence adduced by Dr. Feistmantel,[3] that these beds would have to be classed as rhætic. Of the four species identified, two are said to be European rhætic forms, a third is closely allied to a rhætic species, and the fourth, *Schizoneura Gondwanensis*, though most closely allied to a lower triassic species, belongs to a rhætic genus. Now this evidence, so far as it goes, having regard only to the percentage of similar forms, and not to the total number of species, is stronger than that on which the Umia beds of Cutch were classed as lower oolitic, and the Damuda series as lower triassic, and incomparably superior to that which is said to distinguish the Rájmahál flora as liassic. Why, therefore, does Dr. Feistmantel in this case class the Panchets as "representative of the highest trías (Keuper)"?

The reason is not far to seek. It has already been noticed that the relations of the Rájmahál flora, so far as that flora has any real connexion with European fossil plants, is rhætic rather than jurassic. But the Panchet flora is also rhætic. Now, between the Panchets and Rájmahál there is by far the widest break in the

[1] l. c. See also p. 148.

[2] This species has been re-named by Dr. Feistmantel *Rajmahalensis*. No valid reason, so far as I am aware, has been assigned for the change.

[3] Rec. G. S. I., Vol. IX, p. 65. Two forms of *Glossopteris* have since been added, R. c. G. S. I., Vol. X, p. 139, but they do not much affect the argument, as they are said to pass into higher beds.

whole Gondwána system, a break amply shown to exist both on palæontological grounds, and, which is of far greater importance, on geological evidence. With the Panchet beds the reign of ferns and *Equisetaceæ* appears to end, the flora of the upper beds (I am simply taking Dr. Feistmantel's own data) consists very largely of gymnosperms, ferns being relatively less numerous, although still abundant. The geological break is unmistakeable. In the coal-fields of the Damuda valley, the Panchets, together with the underlying groups, were upheaved and disturbed before the intrusion of the trap dykes believed, on good evidence, to be of Rájmahál age. Now, to admit that the beds above, and those below this huge break, both belong to one of the smallest groups of the European series would be tantamount to confessing the fact that fossil plants are worthless for the determination of minor divisions, consequently the upper beds are pushed up into the lias with which they have little or no connexion, and the lower groups fitted into one of the established grooves in the trias with which they are equally unconnected. I quite admit the temptation, to every one who is fond of order and who prefers certainty to doubt, to adopt this plan of pigeon-holing strata, if I may so term the process; it is neat and compact, and it has only one objection, which is, that it is radically false and unscientific. That the affinities of the Panchet fauna and flora are, on the whole, triassic, is not new, and the only additional evidence obtained of late years, such as the further examination of the reptilian fauna of South Africa,[1] and the classification of the *Labyrinthodontia*,[2] whilst by no means conflicting with the original opinion that the Panchet beds might be lower mesozoic or upper palæozoic, is a warning against an attempt at correlating these Indian formations too closely with the European sub-divisions. To define the relations of the Panchet group by substituting Keuper for trias is, I believe, a retrograde step in the present position of our knowledge; the gain is merely a change in names, not in acquaintance with facts, and the nomenclature is more likely to need subsequent correction.

DAMUDA SERIES: *Mángli beds.*—Before entering into the question of the relations of the Damuda flora, I must devote a few words to the Mángli beds. I believe that Dr. Feistmantel's expressed opinions as to the relations of these beds are untenable. The question is partly palæontological, partly geological, and, as the first alone has been treated by Dr. Feistmantel, I shall deal with it before the other. The opinions from which I dissent will be found at length[3] in a "Note on *Estheria* in the Gondwána Formation," and I would beg any one who wishes fully to appreciate the importance of the facts I am about to state, before going farther, to read Dr. Feistmantel's remarks. He concludes that "the Mángli beds cannot belong to the Damuda series at all, and that they are rather to be considered as the uppermost continuation of the Panchet group." This opinion, it must be remembered, is opposed to my own[4] after I had examined the

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[1] Owen: Q. J. G. S., Vol. XXXII, p. 352, and Brit. Mus. Cat., S. Af. Rept.
[2] Repts. Brit. As. 1874, pp. 150., &c.
[3] Rec. G. S. I., Vol. X, p. 26.
[4] Mem. G. S. I., Vol. IX, p. 326.

rocks, and to that of Mr. Hughes,[1] although the latter was founded on a thorough and exhaustive survey of the whole country.

The plant evidence is very slight, and I do not understand Dr. Feistmantel to attach much importance to it. The only recognizable fragments consist of two stems, and these are so poorly preserved that Sir C. Bunbury,[2] who had, I believe, quite as good specimens as those examined by Dr. Feistmantel, was uncertain whether the one was a lycopod *(Knorria)* or a conifer, and whether the other should be referred to *Stigmaria* or to a fern. Dr. Feistmantel may be correct in saying that he is "convinced" that the first is a conifer and belongs to *Palissya*, but it may fairly be questioned whether the suggested identification of such fragments with the rhætic *P. Brauni* is of any importance. The other specimen Dr. Feistmantel says "is certainly a fern stem" and very similar to those described from the rhætic beds in Bavaria. This may be quite correct, but the value of the evidence is so small that it may safely be disregarded until very much more is known of fossil fern stems. As to the supposed *Palissya*, a stem, which is not uncommon locally in the ironstone shales of the Damuda beds, has a striking resemblance to the Mángli fossil; so far as I can judge (the question is one for a botanist, and my knowledge of the science is insufficient for my opinion to have any weight), the resemblance is as close as that of the Mángli stem to *Palissya Brauni*. As, moreover, it has been shewn by Heer[3] that fragments of the Permian *Voltzia Hungarica*, in which the leaves are preserved, but the leaf-scars (*Zapfen*) are wanting, can scarcely be distinguished from the rhætic *Palissya Brauni*, it may be doubted if the leaf-scars alone, all that is preserved in the Mángli stems, are sufficient for specific identification. The plant evidence, from such fragments, may be safely dismissed as worthless.

The animals of the Mángli beds are of more importance. They consist of *Estheria* and a Labyrinthodont, *Brachyops laticeps*. Of the former Dr. Feistmantel says[4]—

"There are certainly two forms, a larger and a smaller one—

"*a.—Estheria Mangaliensis*, Jones . . . . This is the larger form, which Mr. Jones described first from Mángli . . . On some specimens *E. Mangaliensis* is only represented, while on some others it is mixed with the other smaller form, and still, on some others, this latter only is predominant.

"Jones gave several figures which all indicate the larger form *E. Mangaliensis* J. As to the age Mr. Jones considered these beds, for certain reasons, as Rhætic, and now Professor Geinitz describes the same species from beds of the same age in South America.

"*b.—Estheria comp. minuta* var. *Brodieana*, Jones. This form was not described; it is, however, as frequent as the larger one. From the size and form, and from the structure of the shell, they can safely be taken as very closely allied to *Estheria minuta* var. *Brodieana*, Jones, which, as Mr. Jones indicated so distinctly and exhaustively, is characteristic of the rhætic beds."

"This smaller form the Mángli beds have in common with the Panchet group."

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[1] Mem. G. S. I., Vol. XIII, p. 71.
[2] Q. J. G. S., Vol. XVII, 1861, p. 349.
[3] Verh. K. K. Geol. Reichsanst. Wien., No. 2, 1877, p. 43.
[4] Rec. G. S. I., Vol. X, p. 27.

The following extract[1] from Professor Rupert Jones' own paper "on Fossil Estheriæ and their Distribution" will show whether the smaller form was or was not described :—

"7. *Estheria Mangaliensis*, Jones. At Mangali in Central India, about sixty miles south of Nagpur, the Rev. Messrs. S. Hislop and R. Hunter discovered in 1853 a fossiliferous, brick red, laminated sandstone, which contains remains of plants, of Ganoid fishes, and of Labyrinthodont reptiles (*Brachyops laticeps*, Owen) and wide-spread, thin layers of *Estheriæ*. *These, though of various sizes and somewhat different outlines, are all referable to one species*, conditions of growth being sufficient, in my opinion, to account for all the seeming varieties. This *Estheria* (*E. Mangaliensis*) is not without close alliances (so far as the carapace is concerned) to other species, fossil and recent, as is generally the case; *but it gives no direct evidence as to its geological horizon*. . . . .

". . . . Another locality for *Estheria* in Indian strata of approximately the same age has been found by Mr. W. T. Blanford near Pacheet in Bengal. Dr. T. Oldham kindly sent me a sample of this Estherian shale; but I cannot say more than that *this Estheria seems to be the same as the smaller specimens from Mangali.*"

I have distinguished three sentences with italics, and it is quite unnecessary to show how completely they disprove Dr. Feistmantel's supposition that the smaller form was not described, and that Professsor Rupert Jones considered the beds rhætic. Dr. Feistmantel was probably not acquainted with Professor Rupert Jones' paper in the "Quarterly Journal," but in the monograph of *Estheriæ* published by the Palæontographical Society, and quoted by Dr. Feistmantel, the dimensions of several specimens of *E. Mangaliensis* are given, varying in their longest diameter from less than $\frac{1\frac{1}{4}}{12}$ to $\frac{4}{12}$ of an inch, and instead of there being on the plates "several figures, which all indicate the larger form," of the five views of the whole carapace, one only, fig. 16, represents the larger form, three figures, 21, 22, and 23 represent the smaller form, and one figure, 20, is intermediate in size. All these figures are on the same scale, being magnified six diameters, so that the distinction is manifest at a glance.

I ought to add that both Mr. Hislop[3] and I[4] fell into the error of supposing that two species of *Estheria* occurred at Mángli, before Professor Rupert Jones' description was published, and I find that I repeated the suggestion that there were more than one in a later paper.[5] It is only fair to myself to say that the last paper was not originally intended for publication, and that it was printed in my absence. Moreover, the subject was only mentioned incidentally in a brief geological description of the locality, and I did not, like Dr. Feistmantel, attempt to discuss the relations of the species.

I do not think there can be any question that the *Estheriæ* examined by both Professor Rupert Jones and Dr. Feistmantel were identical. Both had some of the original specimens obtained by Mr. Hislop; and those collected by

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[1] Q. J. G. S., 1863, Vol. XIX, p. 149.

[2] Pal. Soc., Foss. Esth., Pl. II.

[3] Jour. Bombay Br. R. A. S., Vol. VI, pp. 201, 203.

[4] Mem. G. S. I., Vol. III, p. 134.

[5] Rec. G. S. I., Vol. I, p. 65. The words were "Estherias (of two species apparently)

myself, and now in the Survey collection, came, I believe, from the same quarry. These *Estheriæ* are extremely abundant at the spot, and both the larger and smaller forms are found in profusion.

Of course, I do not mean for a moment to assert that Professor Rupert Jones is infallible. He may be wrong, and Dr. Feistmantel may be right. But considering that there is scarcely any constant difference in size or form between *Estheria minuta* var. *Brodieana*, and the smaller variety of *E. Mangaliensis*, and that the only essential distinction appears to be in the microscopical structure of the carapace, I am myself disposed to think it more probable that Professor Rupert Jones was right in the identification of the small Mángli *Estheria*, because he had studied the whole genus, and figured the various forms with their microscopical structure, whilst Dr. Feistmantel had only a few forms for comparison, and has omitted all mention of microscopical structure, which, I believe, he has not examined with anything more powerful than a pocket lens.

The statement that "Mr. Jones considered these beds, for certain reasons, as rhætic" may be compared with the extract from Mr. Jones' own paper. It is true that he suggested that the beds might be triassic or rhætic, but the statement was never made in the unqualified manner in which it is quoted.[1] Mr. Hislop, certainly, in his last letters,[2] as quoted by Dr. Feistmantel, expressed an opinion that the Mángli beds "lie above the coal strata," and in one sense he was right, for the Kámthi beds, to which, as I will show presently, the Mángli beds clearly belong, are higher than the Barákars, the coal-bearing group of the Central Provinces, but in the very same sentence he writes of the Korhádi shales, which are Talchir beds, and consequently at the base of the whole Gondwána system, being also above the Umret coal (Barákar). It is scarcely fair to Mr. Hislop, and it is most unfair to Mr. Hughes, to quote the views of the former, expressed before any thorough examination of the country had been made, in opposition to those of Mr. Hughes, who has mapped the whole district closely.

With regard to *Brachiops laticeps*, Dr. Feistmantel is quite correct in saying that Labyrinthodonts occur in the European Keuper, and, he might have added, in the rhætic and jurassic also. The nearest allies of *Brachiops*[3] are *Micropholis Stowii* from the Beaufort beds of the Karoo series in South Africa, *Rhinosaurus Jasikovii* from the Russian oolite and *Bothriceps Australis* from unknown rocks in Australia. The first named is more closely allied than the others, and it occurs in the same beds with the *Dicynodontia*, *Theriodontia* and other South African fossil reptiles. The connexion is of small value as an indication of age, but important as showing the relations of the Indian Gondwána fauna with the ancient life of South Africa and Australia.

[1] At p. 81 of the monograph Professor Jones certainly says that he ventures still to regard these beds as belonging to the rhætic formation, but in the table shewing distribution opposite p. 114, referring to the species classed as rhætic, he writes, "The adoption of this stage for the *Estheriæ* from India and America is merely provisional; they may be triassic."

[2] Q. J. G. S., Vol. XX, 1864, p. 282.

[3] Q. J. G. S., 1859, p. 642,—Repts. Brit. As. 1874, pp. 150, 160.

The Estheria from Kawarsa.—Having thus far treated the purely palæontological affinities of the Mángli beds, I will, before proceeding to the geological argument, advert to the Kawarsa *Estheria*. After a few notes on the *Estheria* from the Panchets, which Dr. Feistmantel says "is certainly identical with the smaller form of *Estheria* in the Mángli beds, mentioned as *Estheria minuta*, var. *Brodieana*, Jon.,"[1] he proceeds to discuss the occurrence of apparently the same crustacean at Kawarsa. The following are extracts from the account given[2]:—

"The Kawarsa beds occur near the southern[3] margin of the basin, and Mr. Hughes speaks of them as several hundred feet from the base of the series. They have yielded some broken plant-remains and *Estheria*

"*a.*—An *Equisetaceous* stalk, pretty distinct; it belongs to that group of forms which generally are termed *Phyllotheca*. . . . .

"*b.*—A fragment of an oblongly lanceolate leaflet, with marked ribs, which might belong to *Schizoneura*, Schimp.

"*c.*—Some broken specimens of *Glossopteris* occur very rarely in comparison with those so richly represented leaves at Nagpur, and elsewhere in the Damudas; and I have no doubt that these beds, near Kawarsa, are younger than all the real Damudas, including the Kámthi Raniganj group.

"To this indication now is to be added the occurrence of *Estheria*, which is certainly identical with that in the Panchet group, the state of preservation and the size and form[4] being identical; and is therefore to be considered as very likely *Estheria minuta* var. *Brodieana* Jon.

"From the occurrence of the *Estheria*, an animal fossil which is still so frequent in the Mángli beds and in the Panchet group, and from the scarcity of plants altogether[5] and from the state of the rock, it would, I think, follow that the locality at Kawarsa is scarcely to be considered as representative of any group of the real Damuda beds, the fossils of which are everywhere so different from those both of the Mángli and the Kawarsa beds?"

Contrast with the last passage and with the above list of plants the following list[6] of the same plants from Kawarsa as supplied by Dr. Feistmantel himself to Mr. Hughes, and published by the latter:—

"1. *Phyllotheca Indica*, Bunb. Established by Bunbury as an Indian type. It is one of the *Equisetaceæ* of the genus *Calamites* (Suckow) and reminds one of *Calamites*

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[1] Dr Feistmantel adds, "I compared specimens from both localities, and I could not find any difference." This had been done before by Professor Rupert Jones (Q. J. G. S., Vol XIX, p. 149), Mr. Hislop (Jour. Bom. Br R. A. S, Vol. VI, p. 201) and myself (Mem. G. S. I., Vol. III, p. 134, with the same result, but, as was pointed out by Professor Jones, the condition of the Panchet species is such as to prevent the identification from being certain.

[2] Rec. G. S. I., Vol. X, p. 28.

[3] South-west margin would be more correct.

[4] The value of size and form in determining species of *Estheria* will have been seen from the details already given as to the differences between *E. Mangaliensis* and *E. minuta* var. *Brodieana*. I do not understand how the "state of preservation" in fossils can be employed as a means of identification.

[5] This is another argument which could not be used by any one having a knowledge of the rocks in the field, for the Kamthi group is remarkable for the paucity of organic remains. Surely, too, Mr. Hughes and I, who examined the beds at Kawarsa, are better qualified to judge of the "state of the rock" and its bearing upon the relations of the beds than Dr. Feistmantel is from the examination of half a dozen cabinet specimens derived from a single bed.

[6] Mem. G. S. I., Vol. XII, p. 70.

arenaceus, Jäger. It might perhaps be considered as only the stalk of *Schizoneura* Schimp.

"2. *Schizoneura*, Schimp. fragments.

"3. *Glossopteris Indica*, Schimp. (*Glossopteris Browniana*, var. *Indica*, Bgt.), a piece of a large leaf with large reticulations.

"4. *Glossopteris Browniana*, var. *Australasica*, Bgt. Some smaller leaves than the above may be determined as being of this species."

Surely the species quoted are well known and characteristic Damuda fossils, but even if the specific identity be not certainly determined, what can be the meaning of the statement that the fossils of "the real Damuda beds are everywhere so different" from those of the Kawarsa beds? All of the species named are found either in the typical Kámthi beds near Nagpur, or in the Damuda rocks of Bengal.

In another paper Dr. Feistmantel writes thus,[1] adverting to the occurrence of *Glossopteris* fronds in a fragmentary condition amongst the Panchet beds—

"This manner of preservation resembles that in the Kawarsa beds of the Chanda district, where *Glossopteris* occurs also in a very fragmentary state, and again associated with *Estheria* (the form as in the Panchets and in the Mángli beds). In my note on the *Estheria* beds in India I have already pointed this out, and I repeat again that the Kawarsa beds very likely are on the horizon of the Panchets in Bengal.

This can only mean that the fragmentary occurrence of *Glossopteris* fronds indicates contemporaneous deposition! Fragments of leaves are the rule in all plant-bearing formations, so far as my experience goes, but no collector brings them away when he can obtain more perfect specimens.

The value of the observation as to the rarity of occurrence of *Glossopteris* at Kawarsa will be best appreciated in connexion with the fact that Dr. Feistmantel has never visited the locality and has seen only about half a dozen specimens.

I am sorry to be obliged to expose in this manner the value of the arguments put forward, but leaving them without answer has already done mischief, and it is necessary to show the kind of data upon which Dr. Feistmantel bases his conclusions in this case. His reason for arguing that the Kawarsa beds are not Damudas are probably the following. Learning that Dr. Geinitz had found an *Estheria*, apparently identical with *E. Mangaliensis*, in some beds said to be of rhætic age in America, Dr. Feistmantel appears to have concluded rather hastily that the Mángli beds were of the same age, and as this view received some support from Professor Rupert Jones' original remarks, it was accepted. The occurrence of the Mángli *Estheria* with characteristically Damuda plants at Kawarsa was a difficulty, and hence the very curious arguments which were employed to make out that these Damuda plants prove that the beds in which they occur are not of Damuda age. Of course the circumstance that one form of the Mángli *Estheria* occurs with Damuda plants about 30 miles away at Kawarsa is of vastly greater importance in determining the relations of the Mángli beds than the existence of the same *Estheria* with rhætic plants in South America.

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[1] Rec. G. S. I., Vol. X, p. 139.

There is one more point to notice. I cannot agree with Dr. Feistmantel's opinion that "*Estheria* has hitherto been neglected in India in the discrimination of horizons," [1] and I think this is a fair instance of the manner in which Dr. Feistmantel often writes of all who have preceded him. Whether he *intends* in this case to charge his colleagues and Mr. Hislop with neglect or not is not the point at issue. I do not accuse him of *intentional* injustice; I simply question the accuracy of his statement All the fossil species of *Estheria* hitherto found in India have been described and figured, and if this has not been done "in India" surely Anglo-Indians are not to be blamed because they send fossils for description to competent naturalists in Europe. Every known discovery of *Estheria* in the Gondwána beds, either by Mr Hislop or the Survey, has been noticed in print. nor is there a single occurrence noted by Dr. Feistmantel which had not been previously recorded. Why, then, are we charged with neglect? The evidence I have given above will enable any one to compare Dr. Feistmantel's *use* of *Estheria* with the previous "neglect," and to determine which course is most in accordance with scientific truth.

Geological evidence.—Thus far I have treated the question of the palæontological relations of the Mángli beds, my object being to shew how untenable Dr. Feistmantel's views are. But it must not be forgotten that these views were opposed to Mr. Hughes' and my own, founded upon geological evidence. As my own examination of the rocks was only preliminary, I depend chiefly upon Mr. Hughes, who has examined the whole of the Wardha coal-field in detail. I have accepted Mr. Hughes' views when they differ from my own in the case of the Maleri beds, so it is not merely because our opinions coincide as to the Mángli beds that I quote my colleague's determinations, but solely because he had fuller opportunities for coming to a decided conclusion.

Mr. Hughes' [2] views as to the beds of Mángli are, I think, perfectly clear. He does not express any doubt as to the position of the strata; he places them amongst the typical Kámthi beds, and estimates that they are about 700 feet above the base of the group. It is true that no higher beds than the Mángli beds are seen in the immediate neighbourhood, because the Deccan traps rest unconformably on the Gondwánas close by, but there are higher Kámthi beds elsewhere. A few pages farther [3] the occurrence of red argillaceous shales, like those of Mángli, is noted north-east of Balár hill, near Wún, and Mr. Hughes remarks that as they should not be more than 400 feet above the coal-measures, the horizon assigned to the Mángli beds is probably not too low. This, of course, implies that the Mángli beds are probably the equivalents of those seen near Balár hill. Now, the Kawarsa and Punwat beds are nearly on the strike of these beds north-east of Balár hill, and therefore presumably on nearly the same horizon as the Mángli beds, the rock containing *Estheria* at Punwat [4] resembling the Mángli shale in mineral character. But above the beds at Kawarsa and Punwat are all the sandstones of Malargarh hill, which are characteristically Kámthi. There is no part of the Wardha field

[1] Rec. G. S. I., Vol. X, p. 30.
[2] Mem. G. S. I., Vol. XIII, p. 71
[3] L. c., p. 75.
[4] L. c., p. 77.

in which the geology is clearer than in this ground, and there cannot, I think, be any reasonable doubt that, so far from the Kawarsa beds being higher than the Kámthis, they are clearly intercalated in the group, and are much nearer to the base than to the top. I have examined the ground more than once, and my preliminary map agrees with Mr. Hughes' finished survey. I cannot see how there can be any reasonable question that both the Kawarsa beds and the Mángli beds are typical Kámthis. I am aware that this is not stated so emphatically and clearly by Mr. Hughes, but he could scarcely have anticipated that his opinions would be disputed in the publications of the Survey by one who had never seen the ground, and who depended upon such palæontological arguments as those I have just exposed.

Flora of the Damuda series.—I have already in the first part of this paper dealt at sufficient length with the evidence brought forward by Dr. Feistmantel to shew that the Damuda flora is characteristically mesozoic. That the generic relations of this flora are mesozoic rather than palæozoic; that there is an almost total want in the Damudas of the characteristic forms found in such abundance in the European coal-measures; that *Lepidodendron, Sigillaria* and a host of other carboniferous types are absent; and that their place is taken by plants more nearly affined to mesozoic forms, have been admitted by everybody, but precisely the same is true of the flora intercalated with beds containing typical carboniferous marine fossils in Australia. The fact that the Damuda flora consists mainly of ferns and *Equisetaceæ*, and the very subordinate part played in these beds by cycads and conifers are palæozoic characters, although they are quite insufficient alone to prove that the beds are palæozoic. My object in the present instance, as in my last paper, is not to prove the Damudas palæozoic, but to vindicate Dr. Oldham and his colleagues of the Survey from Dr. Feistmantel's attacks, and to show that their opinion, that the Damuda flora has little or no connexion with any known European fossil flora, and that the former is much more nearly related to the coal flora of Australia, is more correct than Dr. Feistmantel's. The estimate of the relations of the Damuda flora depends upon two distinct questions—

1. Is the Damuda flora more nearly affined to any European fossil flora than it is to that found in certain Australian beds?
2. What are the relations, geological and palæontological, of those Australian beds?

I have already stated the facts as they were known to me,[1] but I find I have omitted several items of importance in relation to the Australian beds. In consequence of these omissions, Dr. Feistmantel's reply appears stronger than it really is.

I write under correction, and with a full sense that I am dealing with a subject of which I am not a master, but merely a student, but still I think that the plan adopted by Dr. Feistmantel to prove the Damudas mesozoic involves a fatal error. From the whole of the Damuda flora he takes a plant here and a plant there, shows that it is related, now to a triassic, now to a rhætic, now to a juras-

[1] Rec. G. S. I., Vol. IX, pp. 82, &c.

sic European species, and then he points out that the sum of these relations exceeds the connexion which exists between the Damuda flora and that found in the Australian beds. But the Australian flora with which comparison is made is confined to one group of rocks and has been but imperfectly investigated; whilst against the identifications and assimilations with this one poor assemblage of plants, consisting of only about twenty fairly known species, there is urged every possible connection which can be detected between Damuda plants and those found in all the various widely exposed floras of Europe between cretaceous and permian. Even under these conditions, I doubt if Dr. Feistmantel has proved his case. That the Damuda flora has a mesozoic facies is no new discovery; the fact has been admitted, I believe, by every writer on the subject, whatever his opinions as to the age of the beds, and the same is notoriously the case with the Australian Newcastle flora, but I do not think that either the age or homotaxis of a group of rocks can be determined by comparing the flora with several distinct assemblages of plants of varying age, so well as by showing the connexion with the species found in one defined group.

Relations of Damuda flora to European trias and Australian beds respectively.— To show the views I have to answer I make a few extracts from Dr. Feistmantel's later papers, those written since my own appeared—

"The affinities of our Damuda flora with that of the mesozoic epoch and especially of the triassic formation are overwhelming.[1]

"We have in all the special collections unmistakeable evidence for the supposition of M. Bunbury as to the mesozoic, and, as I add, triassic age of the Damuda flora.

"Already in the old collections from Raniganj there were proofs enough!"[2]

[That is before the discovery of the Karharbári fossils. The remainder of the sentence has already been discussed.]

"The Damuda flora exhibits itself quite decidedly as mesozoic and most naturally as of triassic age.[3]

"We know that the Panchet group overlies immediately the Raniganj group, which itself is Lower Triassic.[4]

"I have also shown that the Damuda are Lower Triassic."[5]

And in various tables showing the relations of the Gondwána groups to European strata the Damuda series is always classed by Dr. Feistmantel in accordance with his original determination as the equivalent of the Bunter (lower trias).[6]

Some Karharbári plants are doubtless allied to Bunter species, and Dr. Feistmantel was perfectly right in including these forms in the Damuda flora, because

[1] Rec. G. S. I., Vol. IX, p. 117.
[2] Ib., p. 119.
[3] Ib., p. 121.
[4] Rec. G. S. I., Vol. X, p. 28.
[5] Pal. Ind., Ser. II, 2, p. 160.
[6] Rec. G. S. I., Vol. IX, p. 125; Pal. Ind., Ser. XI, p. 2; Geol. Mag. Dec. 2, III, 1876, p. 491. Leon. Gein. Neues Jahrb. 1877, p. 159.

the Karharbári beds had always been classed by the Survey as lower Damudas until the plant-remains were examined. I shall, however, show presently that the Karharbári beds must be separated from the true Damudas. One of the extracts I have above quoted shows that Dr. Feistmantel considers that the relations of the Damuda flora to that of the European trias is well marked, independently of the Karharbári plants.

It is as well here before turning to the connexion between the Damudas and the Australian rocks to recapitulate the succession in descending order of the New South Wales beds as given by Mr. Clarke and Mr. Wilkinson.[1] Dr. Feistmantel's classification I will dispose of hereafter. The following is the succession:—

1. Wyanamatta beds.
2. Hawkesbury beds.
3. Upper coal measures, or Newcastle, Wollongong, and Bowenfels series.
4. Lower coal measures associated with marine beds.
5. Lepidodendron beds (Devonian).

Dr. Feistmantel in the paper to which I am especially replying admits a certain connection between the Damuda flora and that of the upper coal measures of Australia. Yet he writes—in this case referring to the upper coal measures No. 3—

"Thus it seems that the evidence of a connection with the Australian coal measures is very weak, while the fossils enumerated as common with European Trias are unmistakeably identical."

It is only fair to say that the most of Dr. Feistmantel's remarks on the dissimilarity of the Damuda and Australian floras refer to the lower coal measures of Australia, and to these I will proceed presently. I am however, I believe, stating his views fairly when I conclude that he considers the connexion between the Damuda flora and that of the European lower triassic rocks stronger than that which unites the Damudas with the upper coal measures of Australia. To show how far this view is tenable, I place in parallel columns (1) Dr. Feistmantel's own list of Damuda plants,[3] *minus* the Karharbári forms which are not known to occur in true Damuda rocks, (2) Schimper's list of Bunter (lower triassic) plants,[4] and (3) the list of Australian species from the upper coal measures obtained by adding together the names given by McCoy, Morris, and Dana.[5]

[1] Q. J. G. S., 1861, Vol. XVII, p. 358. "Mines and Mineral Statistics of New South Wales," Sydney, 1875, p. 128.

[2] Rec. G. S. I., Vol. IX, p. 122. Only one species, *Voltzia heterophylla*, has been shown to be specifically identical with a European plant. *Voltzia acutifolia* is, I understand, a synonym of *V. heterophylla*, and the connexion in other species is merely generic.

[3] Rec. G. S. I., Vol. IX, pp. 119-121, and subsequent additions.

[4] Traité de Paléontologie Vegétale, Vol. III, p. 645.

[5] Q. J. G. S., 1861, p. 359.

BUNTER (*Europe*).

EQUISETACEÆ.

Equisetum Mougeotii.
E. Brogniarti.
Schizoneura paradoxa.

FILICES.

Neuropteris grandifolium.
N. Voltzii.
N. intermedium.
N. elegans.
Pecopteris Sultziana.
Crematopteris typica.
Anomopteris Mougeotii.
(*Sphalopteris, Mougeotii*) stem.
(*Chelopteris Vogesiaca*) stem.
(*C. Voltzii*) stem.
(*C. micropeltis*) stem.
(*Cyatheopteris tessellata*) stem.
(*Bathypteris Lesangeana*) stem.
(*Caulopteris? Maraschiniana*) stem.
(*C.? Læliana*) stem.
(*C. Festariana*) stem.

CYCADEACEÆ.

Pterophyllum Hogardi.
Zamites Vogesiacus.

DAMUDA.

EQUISETACEÆ.

**Schizoneura Gondwanensis.*
Sphenophyllum speciosum (*v. trizygia*).
†*Phyllotheca Indica.*
†*Vertebraria Indica.*

FILICES.

Actinopteris Bengalensis.
†*Sphenopteris polymorpha.*
S. (*Dicksonia*), sp.
†*Alethopteris Lindleyana.*
†*A.* conf. *Whitbyensis.*
A. phegopteroides.
Tæniopteris (*Angiopteridium*), sp.
T. (*Macrotæniopteris*) *danæoides.*
T. (*M.*) *Feddeni.*
Palæovittaria Kurzi.
†*Glossopteris Browniana.*
†*G. Indica.*
†*G. communis.*
†*G. angustifolia.*
†*G. leptoneura.*
†*G. musæfolia.*
†*G. stricta.*
†*G.* several other species.
Sagenopteris pedunculata.
S. polyphylla.
Gangamopteris Whittyana.
G. Hughesi.
Belemnopteris Wood-Masoniana.

CYCADEACEÆ.

†*Noeggerathia Hislopi.*
N. , sp.
Pterophyllum Burdwanense.

NEWCASTLE BEDS (*Australia*).

ALGÆ?

(*Anarthrocanna.*)
(*Cystoserites.*)
(*Confervites tenella.*)

EQUISETACEÆ.

†*Phyllotheca Australis.*
(*P. ramosa.*)
(*P. Hookeri.*)
†*Vertebraria Australis.*

FILICES.

Sphenopteris lobifolia.
†*S. alata*, var. *exilis.*
S. hastata.
S. Germani.
S. plumosa.
S. flexuosa.
†*Alethopteris Australis.*
Pecopteris? odontopteroides.
Otopteris ovata.
†*Glossopteris Browniana.*
†*G. linearis.*
†*G. ampla.*
†*G. reticulum.*
†*G. elongata.*
G. cordata.
†*G.* several other species.
Gangamopteris (*Cyclopteris*) *angustifolia.*

CYCADEACEÆ.

Noeggerathia (*Zeugophyllites*) *elongata.*
†*N. spatulata.*
N. media.

Coniferæ.	Coniferæ.	Coniferæ.
Voltzia heterophylla.	(*Palissya ?* sp.), stem.	Some undetermined forms.
(*V. acutifolia*).		
Albertia latifolia.		
A. Brauni.		
A. elliptica.		
A. speciosa.		
A. Schaurothiana.		
Taxites ? Massalongi.		
T. ? Vicentinus.		
Monocotyledones.		
Yuccites Vogesiacus.		
(*Spirangium regulare*—fruit only.)		
Œthophyllum speciosum.		
Æ. stipulare.		
Æ. Foetterleanum.		

In the above lists names placed between parentheses may be neglected; they are either too obscure for recognition, or synonymous, or else founded solely on parts of the plant, such as stems or the fruit alone, which cannot be fairly compared. Species representing each other in the Bunter and Damuda flora are marked with an asterisk (*), allied forms in the Damuda and Australian flora with a dagger (†). It is possible that some of the Australian species of *Sphenopteris* and *Glossopteris* should have been omitted, as they are not sufficiently defined for their relations to be known,[1] but I wish to place the whole evidence, so far as I am acquainted with it, before my readers. Doubtless, too, some species have been added to the Bunter flora since Schimper's work was published, and some rectifications may have been introduced.

The above lists, moreover, are not in all cases fairly comparable, the Bunter flora of Europe and the Damuda flora of India having been far better explored than that of Australia. Moreover, we may be sure that any point of resemblance, however slight, between the Bunter and the Damuda flora has been noticed by Dr. Feistmantel, whilst it is far from equally certain that the full connexion between the Damuda and Australian floras has been traced by an equally competent judge. I have classed all the species of *Glossopteris* in the Damuda series and the Newcastle beds, with one exception, as allied to each other, and I believe I am fully justified in doing so, but possibly one or two forms may not be so nearly related as I suppose. But in this subject I am *ultra crepidam*. I only take up a matter with which I have an imperfect acquaintance because it appears to me unfair to the Survey that only one side of an argument should be stated, and because, in self defence, I am bound to show that I really have stronger reasons for objecting to Dr. Feistmantel's views than he is willing to admit.

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[1] I have omitted a form called *Austrella rigida*, founded on what appears to me to be nothing but rootlets, perhaps of *Vertebraria*. Precisely similar bodies abound in Damuda beds, but are, of course, worthless for comparison.

I take the Bunter flora for comparison because Dr. Feistmantel has repeatedly stated that the Damudas are of lower triassic age, but I may add, that were I to give the lists of known plants from Keuper or rhætic, (the flora of the Muschelkalk is too poor for comparison,) the result would be the same. There are a few allied forms in each of these subdivisions,[1] and probably there are more in the rhætic than in the trias. There are also certain Damuda forms such as *Phyllotheca Indica; Sagenopteris, Alethopteris Lindleyana* and *A.* conf. *Whitbyensis* which are much closer to jurassic European forms than to triassic, and it may be remembered that many European palæontologists long classed the Damudas as oolitic. In short, so far from its being the fact that there is a distinct connexion between the Damuda flora and that found in European lower triassic rocks, the truth is really that there is not so strong a resemblance between Damuda and Bunter plants as there is between Damuda and jurassic. On the other hand, I do not see how any one can look over the list given above without seeing the very marked similarity between the Damuda flora and that of the Newcastle beds in Australia. So marked is this, that even if the Karharbári forms be included in the Damuda flora as Dr. Feistmantel has done, it still appears to me that the former is more closely allied to the Australian than to the Bunter flora.

The conclusion at which I arrive is, that instead of the evidence which connects the Damuda formation with the Australian carboniferous rocks being about equal to that between the Damudas and European trias, as I at first thought, the former connexion is more marked than the latter.

The relations of the lower Australian beds.—I pass on to the second question. The third point on which, in Dr. Feistmantel's opinion, my conclusions were "rather premature"[2] related to the lower Australian coal strata, and, as he puts his thesis, "The analogy with the flora of the lower coal strata in Australia is comparatively weak'.[3] I do not think this is an answer to my argument, because I never insisted upon the affinity between the Damuda flora and that of the lower coal measures of Australia. What I did show was[4] that the connexion between the various groups of the coal-bearing series in Australia, from the Wyanamatta beds to the lower coal measures, (excluding, of course, the *Lepidodendron* beds,) was exactly the same as that on the strength of which Dr. Feistmantel had just argued that the whole of the lower Gondwánas were triassic, and if the argument were applied to the Indian beds, it was equally valid in justifying the classification of all the Australian rocks below the Hawkesbury beds (and I might even have included the Hawkesbury and Wyanamatta

[1] The only Keuper plants which have any marked relations to Damuda species, so far as I am aware, are some forms of *Pecopteris* or *Alethopteris* allied to *A. Whitbyensis*, and *Noeggerathia Vogesiaca* (*Macropterygium Bronnii*), the latter alone being of any importance. Perhaps there may be a slight similarity between some of the Keuper species of *Pterophyllum* and *P. Burdwanense*. It should be remembered that only one specimen of *Pterophyllum Burdwanense*, and one of *Noeggerathia* cf. *Vogesiaca* have yet been found in Damuda beds.

[2] Rec. G. S. I., Vol. IX, p. 117.

[3] And again, p. 121, "What is the analogy of our Damuda series with the lower coal measures in Australia?"

[4] Ib., p. 83.

beds) as carboniferous. I then shewed the connexion between the flora of the upper and lower coal measures in Australia taken together, and that of the Damuda beds.

The above would really be a reply to all that is stated in the sentence above quoted. Dr. Feistmantel has not answered me. He has merely traversed an argument which differs materially from that I used. But in the course of his remarks he enters into the real question at issue and makes several atements which, if correct, would have some weight as opposed to my opinion. I shall, therefore, shew how far these statements are in accordance with the facts made known by various Australian geologists.

I have already twice had to refer to Dr. Feistmantel's classification of the Australian rocks.* Here it is[1]—

Upper coal measures.	Beds in Tasmania, Queensland, Victoria.	Without New South Wales.	No animals.
	Clarence river.		
	Wyanamatta beds.		
	Hawkesbury beds.		
	Bowenfels.		
	Upper beds in Newcastle.		
Lower coal measures.	Beds with marine plants intercalated with plant-beds. Especially Stony Creek, Rix. Ck., Greta, Mnt. Wingen, &c.		
	Again marine beds.		
Culm series.	Smith Creek. Port Stefens.	Lower carboniferous plants with carboniferous animals.	
Devonian.	Goonoo-goonoo.	Plant-remains only.	

* This Dr. Feistmantel states[2] is "the succession of the several strata of the Australian coal formation, as Mr. Clarke communicated it to me in a late paper, and as it is to be foundin his 'Remarks.'" It is to be regretted that Dr. Feistmantel has not given a reference to the Rev. Mr. Clarke's paper, because there is, so far as I can see, nothing in the "remarks" which can be quoted to justify the classification adopted, and the union of the Wyanamatta, Hawkesbury and Newcastle beds into one subdivision as upper coal measures, and their separation from the lower coal measures are so entirely opposed to all that Mr. Clarke has written on the subject, that it is to be hoped Dr. Feistmantel will either publish Mr. Clarke's own words, or admit that he has arranged the section to suit his own views. The beds in Tasmania, Queensland, &c., have nothing to do with the main question and only tend to distract attention from the typical sequence in New South Wales. In the printed paper of Mr. Clarke's,[3] to which we have all hitherto referred for the classification of the Australian (New South Wales) plant-bearing rocks, they are thus arrranged—

1. Wyanamatta beds.
2. Hawkesbury rocks.
3. Coal seams of Newcastle, &c.
4. Lower carboniferous rocks.

[1] Rec. G. S. I., Vol. IX, p. 123.
[2] l. c.
[3] Q. J. G. S., 1861, Vol. XVII, pp. 357, 358, &c.

The last being the "culm" and "Devonian" beds of Dr. Feistmantel's series, with which I have no present concern. No. 3 includes both the upper beds in Newcastle and Dr. Feistmantel's "lower coal measures." In the "Remarks"[1] the *Lepidodendron* beds are noticed under the heading of Middle Palæozoic, all the coal measures of Newcastle are classed in the upper Palæozoic, together with the "lower coal measures" of Dr. Feistmantel, while the Wyanamatta and Hawkesbury beds are treated apart from the others under the heading of Mesozoic or Secondary Formations. Take the following extracts[2] from the "Notes on the Upper Palæozoic Beds" and compare them with Dr. Feistmantel's classification:—

"As far as some of the plants are concerned, it may be admitted that they are in an unsatisfactory condition at present; but the balance in favour of a carboniferous age for the *Glossopteris* beds is, to my mind, conclusive."

The *Glossopteris* beds include both the upper (Newcastle) coal measures and the lower coal seams with marine bands. Again[3]—

"So far, then, the question about the age of some of the Australian coal must be considered as settled; and if, as in Illawarra, the coal beds overlie the marine beds, as they do also in the Fingal district of Tasmania, it would appear that all these separate occurrences belong to one thick series, in which marine beds and fresh-water beds interpolate each other. But assuredly in that case the arrangement adopted must express the order as follows:—

"1. Upper coal measures.
"2. Upper marine beds.
"3. Lower coal measures.
"4. Lower marine beds."[4]

I cannot see how Mr. Clarke can be quoted to justify the removal of the upper coal measures from the palæozoic series in the face of such evidence as this. I beg to call attention to the fact that Dr. Feistmantel always gives his own version of Mr. Clarke's views, whereas I quote Mr. Clarke's published words.

Mr. Clarke may have changed his views (I have no reason to believe he has); he may, like myself, have been guided by Dr. Feistmantel's statement[5] that there is a radical difference between the flora of the upper (Newcastle, Bowenfels) and lower (Stony Creek, &c.) coal measures in Australia. I accepted Dr. Feistmantel's opinion as that of an expert, and was immediately quoted by him as evidence,[6] part of my sentence quoted by him being omitted so as to

[1] Mines and Mineral Statistics of New South Wales, &c., Sydney, 1875, pp. 161...191.

[2] Clarke, l. c., p. 178.

[3] Ib., p. 179.

[4] Mr. C. S. Wilkinson, the Government Geologist, writes thus in the same work, page 128,—"The several divisions of the upper palæozoic series have been named after the localities where they are found to be most typically developed. In descending order they are as follows:—

"Wyanamatta series.
"Hawkesbury series.
"Upper coal measures of Newcastle, Wollongong and Bowenfels series.
"Upper marine beds.
"Lower coal measures.
"Lower marine beds.
"Lepidodendron beds."

[5] Rec. G. S. I., Vol. IX, pp. 70, 71, 121, &c.

[6] I said, Rec. G. S. I., Vol. IX, p. 83, "Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both, although, *from specimens which Dr. Feistmantel has shown*

make it appear that my opinion was founded on my own observations, and not on his. I very greatly regret to say that further experience of Dr. Feistmantel's statements has produced a sceptical spirit, especially when they are in opposition to the evidence of other observers, and I now refuse to admit there is any important distinction between the flora of the upper and lower Australian coal measures until Dr. Feistmantel produces evidence instead of assertions. I think it probable Mr. Clarke will show equal caution. When Dr. Feistmantel's evidence appears, it will remain to be seen how far he has established his thesis. If I appear to be harsh in my judgment, I would refer to the facts I have already pointed out as to the evidence on the strength of which Dr. Feistmantel has over and over again asserted that the Rájmahál flora is liassic, and to his statements about the Mángli beds and the *Lamellibranchiata* of the Umia group.

The original evidence as to the connection between the upper (Newcastle) coal measures and the lower beds of Stony Creek was, that below "grits and conglomerates full of *Pachydomi, Spiriferi, Orthoceratites*, large *Conulariæ, Asteridæ*, *&c.*, ... a bed of shale was reached in which are impressions of *Noeggerathia* (or *Zeugophyllites*), *Glossopteris* (or *Sagenopteris*) and other plants, such as *Cyclopteris*, that look as much like jurassic as any that are so called."[1] In the "Transactions of the Royal Society of Victoria, Vol. VI" (I have not access to the original[2] at present), sections were given by Mr. Clarke from Stony Creek showing the occurrence of *Glossopteris, Phyllotheca* and *Noeggerathia* in the beds below those containing the marine fossils. Take, again, the following extract from the notes by Mr. E. C. Wilkinson, Government Geologist[3]:—

"The collection of fossils from near West Maitland, Greta and Anvil Creek includes *Spiriferæ Conulariæ, Inocerami, Productæ, Fenestellæ, Bellerophon*, crinoidal stems, &c., obtained from the upper marine beds 350 feet above the Anvil Creek coal seam, from which seam I collected the specimens now shown, containing the *Phyllotheca* and *Glossopteris Browniana*. Immediately below this coal are the lower marine beds represented by the specimens of *Spiriferæ, Conulariæ, Bellerophon, Pachydomus, Orthoceras, Euomphalus, Fenestella*, a new species of Starfish, *Chætetes radians*, &c., from Stony Creek, Harper's Hill, Ravensfield, and Singleton. This suite of fossils is especially interesting, as showing not only the range through the coal series of the *Glossopteris* and *Phyllotheca*, plants so abundant in the upper coal measures of Wollongong, Lithgow Valley and Newcastle, but also the association of those plants with the marine fauna of the lower coal measures, thus affording evidence, agreeing with that of the previously mentioned fishes, as to the upper palæozoic age of the New South Wales coal measures"

In the same work, "Mines and Mineral Statistics of New South Wales," several detailed sections are given. In section No. 1, p. 206, bed No. 5 in descending order contains "large fossils, *Fenestella, Inoceramus, Conularia*, &c.;" No. 19 is said to be "full of *Glossopteris, Phyllotheca*, and leaves of ? *Noeggerathia;*" No. 24

(misprinted *shewed*) *to me* there appears to be a considerable distinction in the flora." Dr. Feistmantel quoted this paragraph (Records, Vol. IX, p. 122), but omitted the words in italics, thus making the statement appear to rest on my authority instead of on his own. This, moreover, was emphasized by the concluding portion of the sentence being placed in italics.

[1] Q. J. G. S., 1861, Vol. XVII, p. 360.

[2] The volume is wanting in the Survey library.

[3] Mines and Mineral Statistics, p. 132.

is said to be "full of large *Glossopteris* fronds, &c., same as bed No. 12." Again, at p. 226, in a section of some coal seams and the accompanying shales. The uppermost bed, a coarse conglomerate, is said to be "full of palæozoic fossil fauna, *Conularia, Orthoceras, Producta, Spirifera, Inocerami, Crinoidea, &c.,*" whilst 6 feet lower down is "shale full of *Glossopteris, Phyllotheca* and *Noeggerathia.*"

So far, then, we have evidence of four species of plants in the "lower coal measures." These species are—

1.—*Glossopteris Browniana,* admitted by all to be indentical with the species from the upper coal measures.

2.—*Phyllotheca.*

3.—*Noeggerathia.*

4.—*Tæniopteris* near *T. Eckardi* (this is inserted on Dr. Feistmantel's authority).

Now, where is the evidence that the plants called *Phyllotheca* and *Noeggerathia* from the lower beds are distinct from those in the upper? I have already quoted[1] McCoy's identification of the *Phyllotheca,* apparently from the lower beds of Queensland, with *P. Australis,* the species found in the upper coal measures of Newcastle, &c. Dr. Feistmantel's evidence as to the distinction of the lower coal measures' flora, so far as he has hitherto supplied any facts, amounts to this, that he has seen a *Tæniopteris* from the lower beds which he has not seen from the upper. He may have more evidence, but that produced is certainly not sufficient to justify the rejection of the opinions given by Australian geologists.

The rest of the evidence brought forward by Dr. Feistmantel need not detain us long. He says (I am obliged to re-quote part of the paragraph)[2]—

"As to 3 and 4, of which the first are the upper coal measures of Newcastle, Mr. Blanford himself says, 'Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both,[3] although there *appears to be a considerable distinction in the flora;*' and I would add, No. 3 does not contain any animals,[4] while in No. 4 marine animals are found abundantly."

And again[5]—

"*a.*—The upper portion is marked by a flora, which is abundant. Nos. 1, 2, 3 of Mr. Blanford's list must be referred to this; they contain no marine fossils to indicate a connection with the lower portion.

"*b.*—The lower coal measures are marked by two marine faunas of, as generally taken, a carboniferous age, which separate distinctly these from the upper beds. The flora is, as both Mr. Clarke and Mr. Daintree state, only rare"[6]

Now, this is one of those points on which my ideas are so diametrically opposed to Dr. Feistmantel's that I can only suppose, either that our notions of elemen-

[1] *Ante,* p. 112.

[2] Rec. G. S. I., Vol. IX, p. 122.

[3] See footnote 6, *ante,* p. 138, for the original form of the sentence here quoted and the portion suppressed by Dr. Feistmantel.

[4] This is incorrect of course; a fish has been obtained from the bed.

[5] l. c., p. 123.

[6] No reference is given, and the statement is quite opposed to all the evidence; see the quotations from the sections in "Mines and Mineral Statistics" just given, where shales of the lower beds are said to be full of *Glossopteris, Phyllotheca* and *Noeggerathia.* The section quoted (No. 1, opposite p. 206) is given by Mr. Clarke himself.

tary geological evidence are distinct, or else that Dr. Feistmantel does not mean what his words convey. It is superfluous to point out that if distinction of age were proved by the presence or absence of marine fossils, the *Glossopteris* beds of the lower Australian coal measures must be of a different age from the fossiliferous marine beds with which they are intercalated, because no marine fossils are found in the beds containing the *Glossopteris*. If the lower plant-beds are not different in age from the marine fossiliferous rocks with which they are interstratified, neither can the upper coal measures be shown to be of distinct age from the lower on account of not containing marine fossils.

I have one more extract to make. I hope that it will be understood that in these remarks I am merely taking a few instances from Dr. Feistmantel's papers; I could easily add others. The extract is the following [1]:—

> "In the last publication, "Mines and Minerals of New South Wales," there is a supplementary report by Mr. John Mackenzie on the New South Wales coal fields, in which, on section *b*,[2] is a sketch section from Newcastle to Port Booral, about thirty miles long. In this the difference in the fossil remains of the upper and lower portions of the coal measures is plainly indicated, and also that the upper portion and lower portion are, besides all the differences, slightly discordant."

The fossil differences are, that in the lower portion several marine carboniferous genera occur, and in the upper portion only plants, and that those plants do not include the genus *Noeggerathia* (the plant known by this name is, however, found elsewhere in the same beds) and do include some forms not found in the lower beds. *Phyllotheca* and *Glossopteris* are quoted from both. So far good; now about the discordance. I fear I shall have some difficulty in convincing my readers without showing them the book, but the truth is that all the evidence of stratigraphical relations in the figure quoted consists in coal seams being indicated in three distinct parts of the section, those to the right having a higher dip than those in the middle, and the latter again higher than those to the left. This is all; there is not, so far as I can see, the smallest indication of unconformity, which is, I presume, what is meant by the beds being said to be discordant, since it is the only way in which a distinction between the different groups could be shown in the section. How far Dr. Feistmantel is correct in supposing that the upper and lower coal measures are "slightly discordant" may be judged by the following extracts from the work in which the section cited appears.

Mr. Clarke himself says [3]—

> "The fact that the coal beds overlie or interpolate the marine beds in what is called 'conformable order' ought to be considered a satisfactory conclusion that no break, such as ought to exist under other circumstances, does exist. . . ."

There can, I think, be no question that Mr. Clarke here refers to both upper and lower coal measures; the sentence would be void of meaning otherwise, and in the previous sentence he refers to the occurrence of ganoid fishes, which

[1] Rec. G. S. I., Vol. IX, p. 124.
[2] Evidently a misprint for *section 6*.
[3] Mines and Mineral Statistics, p. 166.

have, so far as I know, only been found in the upper coal measures and overlying groups.

The next two quotations from the same work are from the reports by Mr. Wilkinson, the Government Geologist, and are perfectly clear. He says—[1]

"The upper coal measures in the western district are about 480 feet thick, resting conformably on the marine beds of the lower coal measures."

And again[2]—

"These marine beds are conformable to the overlying plant-beds of the upper coal measures, but rest unconformably on the upturned edges of Devonian strata."

Mr. Clarke, too, in a footnote, p. 170, quotes a report of Mr. Daintree's on the country between Newcastle and Stony Creek, in which the following passage occurs:—"Neither does there seem any reason why Mr. Clarke should not place the Newcastle coal seams (his No. 3, carboniferous group,) in the upper portion of this Stony Creek group, no known unconformity existing." The Stony Creek group is, of course, the same as the "lower coal measures," with marine fossils. Mr. Daintree's opinion is of importance, for he appears to have gone from Victoria to examine Mr. Clarke's sections, the accuracy of which was doubted by the South Australian geologists, and to have confirmed Mr. Clarke's views.

These extracts are, I fear, tedious, but they are too important to be omitted, because they shew that Australian geologists do not admit the existence of any break between the upper and lower coal measures.

The characteristically mesozoic Tæniopteris Daintreei.—So far I have confined myself to the beds in New South Wales. As I stated at the outset, to mix up with them the beds of Tasmania, Queensland and Victoria tends to confuse. But as these latter beds are adduced as evidence of mesozoic age, it is as well to examine the proof. In the case of the Queensland beds, the age may at once be considered as established on trustworthy evidence,[3] the plant layers with *Tæniopteris* and other forms being above strata containing jurassic marine fossils, whilst the beds with *Glossopteris* occur at a lower horizon associated with Palæozoic mollusca, &c., and underlying the jurassic deposits unconformably. Now, the upper Queensland beds[4] are said to contain two species of plants which occur in other parts of Australia. One of these is *Tæniopteris Daintreei*,[5] and the clue afforded

[1] p. 130. [2] p. 132.

[3] Q. J. G. S., vol. XXVIII, 1872, pp. 325, &c.

[4] Rec. G. S. I., IX, pp. 123, 124.

[5] The importance which Dr. Feistmantel attaches to this fossil is noteworthy. Thus, at p. 136 he writes, "The same *Phyllotheca Australis*, McCoy, is also known from Victoria, together with *Tæniopteris Daintreei*, McCoy, which latter in Queensland is considered as characteristic of the mesozoic (upper) coal beds." Again, p. 138, "McCoy described it (*Gangamopteris*) first from some rocks in Victoria, where no marine fossils occur, but where *Tæniopteris Daintreei*, McCoy, is found, which latter in Queensland is considered as characteristic of the mesozoic beds there. With these also *Phyllotheca Australis*, McCoy, occurred in Victoria." Again, at the bottom of the same page, "This *Gangamopteris* is in Victoria found in certainly mesozoic rocks, being associated with *Tæniopteris Daintreei*, McCoy, which is characteristic of mesozoic rocks in Queensland;" and finally

by this fossil to the determination of the age of the beds in Victoria, and the reflected light thus cast upon Indian rocks through *Gangamopteris angustifolia* and *Phyllotheca*, which are associated with *Tæniopteris Daintreei* in Victoria are frequently noticed by Dr. Feistmantel. *Tæniopteris Daintreei* is also noticed as occurring with *Pecopteris Australis* in Victoria, whilst in Tasmania *Pecopteris Australis* and *Glossopteris* occur together.[1] All this is quoted from McCoy,[2] with one slight omission; the specific name of the *Glossopteris* is not mentioned, although McCoy states that it is *G. Browniana*, and as this is admitted to be a palæozoic species, its occurrence with the *Pecopteris* would neutralize the importance of the *Tæniopteris* in any case.

But I cannot understand how Dr. Feistmantel overlooked another remark of Professor McCoy's on the next page, in which it is pointed out that the Queensland specimen called *Tæniopteris Daintreei* is probably different from that of Victoria. Here is the brief description of each form—

> "*Tæniopteris Daintreei*, McCoy, from Victoria.[3] *General character.*—Frond, simple or pinnate, *long, narrow with a thick strong midrib*, from which the veins extend *nearly at right angles* to the lateral edges, either once or twice forked or simple.
>
> "*Tæniopteris Daintreei*, McCoy, *apud* Carruthers, from Queensland.[4] Frond, simple (?), *broad* linear; midrib *somewhat thick*; veins leaving it *at an acute angle*, then passing out at right angles to the margin, once or twice dichotomously divided."

I have italicised portions of the above, and I can only add that so far as I can, without any special botanical knowledge, give an opinion, it appears to me that, judging from the figures in the two works quoted, the two so-called *Tæniopteris Daintreei* of Victoria and Queensland must be very well marked and distinct species. It is scarcely conceivable that they can be specifically identical.

It is true that *Pecopteris odontopteroides* is said to be common to the Queensland jurassic strata and to the Wyanamatta and Newcastle beds of New South Wales. But Carruthers himself points out distinctions in shape between his figures of the Queensland form and Morris' representation of the New South Wales fern, although he believes both to belong to the same species.[5] As there is a strong probability that the Queensland and New South Wales beds are really of different age, it is to be hoped that this question will be re-investigated.

The remainder of the evidence as to the fossil flora of Victoria tends to show that this flora cannot, in all probability, be much newer than the Newcastle beds of Australia. *Phyllotheca* and *Gangamopteris angustifolia* occur in both. It

p. 143, "I must still once more state that the Australian *Gangamopteris* is from mesozoic strata in Victoria, together with *Tæniopteris Daintreei*, McCoy."

[1] Rec. G. S. I., vol. IX, pp. 121, 122, 123.

[2] Prodrome, Pal. Vict., Dec. II, pl. XIV.

[3] Prodrome, Pal. Vict. Dec. II, p. 15.

[4] Q. J. G. S., Vol. XXVIII, 1872, p. 355.

[5] This fern has been referred by Morris and Carruthers to *Pecopteris*, by McCoy to *Gleichenites*, by Dr. Feistmantel to *Thinnfeldia*, and by a Belgian writer, Fr. Crepin, to *Otopteris*—Bull. Soc. Roy. Belg., vol. XXXIX, p. 258. Can all have examined the same fossil? The figures appear to me to show considerable variation.

would, therefore, be of some importance if the beds of Victoria were really connected with the jurassic plant-beds of Queensland. As it is, there is really no evidence, except the plants, to show that the Victoria beds are mesozoic.

Ganoid fish of Australian beds.—Before leaving the Australian beds I have to call attention to the very important evidence as to the age of the whole series in New South Wales, afforded by the remains of fish. I have already shown that Dr. Feistmantel is mistaken in saying that the upper coal measures of Australia contain no animals, and that he has himself mentioned those animals in another page. The known forms consist of ganoid fishes, and the following have been described and figured:—

Palæoniscus antipodeus. From Wyanamatta beds.

Chleithrolepis granulatus. Cockatoo beds between Wyanamatta and Hawkesbury.

Myriolepis Clarkei.

Urosthenes Australis. Newcastle beds.

The question of the relations of these fish has been thoroughly stated by Sir P. Egerton,[1] certainly one of the highest living authorities, and he concludes thus[2]—

"With regard to the larger question of geological period, there apppears to be sufficient evidence to stamp these remains as belonging to the palæozoic age."

He proceeds to give the range of the nearest allies in Europe, and to show that representatives of all the forms named are associated in the greatest numbers in permian strata (Kupferscheifer). It would be easy to quote authorities for the much greater importance to be attached to fish remains as evidence of age than to plants, all I have to do now is to point out that the evidence of the fish tends to place the whole of the New South Wales rocks from the Wyanamatta beds downwards in the palæozoic epoch. It is quite true that in his later papers Mr. Clarke has classed the Wyanamatta and Hawkesbury beds as lower mesozoic, and probably he is right in doing so, but the plant evidence in favour of this view is of precisely the same nature as that on the strength of which *Glossopteris Browniana* and its carboniferous associates were long classed as jurassic. Probably the Wyanamatta and Hawkesbury beds are of the same age as some of the rocks in Victoria, and they may be approximately of triassic age, or they may be partly permian or intermediate between permian and trias, but their horizon is not ascertained with accuracy.

Glossopteris beds in South Africa.—There is another locality in the southern hemisphere, where, apparently, representatives of the Damuda formation may be traced. Dr. Feistmantel's principal object being to trace the connexion between the Damuda plants and the mesozoic flora of Europe, he has alluded but briefly to the African rocks.[3] They are important because although very

[1] Q. J. G. S., 1863, vol. XX, p. 1. [2] p. 4.
[3] Rec. G. S. I., Vol. IX, p. 71.

little is known of their flora, the little that has been ascertained indicates a very close connexion with that of Indian and Australian beds.

The plants occur in the upper groups, the Stormberg and Beaufort beds of the Karoo series; the latter being the principal Dicynodont beds, and containing the following species, which have been described by Mr. Tate[1] :—

Glossopteris Browniana (the specific identification may perhaps be questioned, but the species is doubtless closely allied).

G. Sutherlandi, a narrow form like *G. angustifolia* and *G. leptoneura*.

Rubidgea, Mackayi, very closely allied to the Damuda *Palæovittaria*, if not generically identical.

Dictyopteris simplex; this has been shown by Dr. Feistmantel[2] to be a *Glossopteris* allied to some Indian (Damuda) species.

Some equisetaceous stems referred to *Phyllotheca.*[3]

There is here a remarkable similarity to the Damuda flora. Only ferns and *Equisetaceæ* are known; all the ferns belong to the simple-leaved forms so abundant in the Damuda beds, and three out of the five plants belong to *Glossopteris*. There is nothing approaching to this amount of similarity in any known European fossil flora, and the close connection between this ancient association of plants in Indian, South African and Australian strata tends strongly to support the idea of a former land connection between these countries, a probability which is strengthened in the case of South Africa, by the representation of certain Rájmahál forms in the jurassic Uitenhage series, and by close alliances between jurassic and cretaceous marine fossils belonging in some cases, in all probability, to littoral forms. The relations of the Panchet *Dicynodon* and the Mángli *Brachyops* to African forms are also worthy of notice.

KARHARBÁRI GROUP.—A few words are necessary as to the reasons for distinguishing this group. The coal-bearing rocks of the Karharbári coal field were originally classed as Barákar (Lower Damuda) by the Survey,[4] but after the fossils associated with the coal had been determined by Dr. Feistmantel,[5] the

[1] Q. J. G. S., 1867, p. 140. [2] Rec. G. S. I., Vol. IX, p. 73.

[3] Besides these Dr. Feistmantel notices, Rec. G. S. I., Vol. IX, page 73, the occurrence of a species probably belonging to *Gangamopteris*, "described by Mr. Tate, from the Karoo beds (triassic) in South Africa as *Cyclopteris Jenkinsiana.*" A reference to the original description (Q. J. G. S., 1867, Vol. XXIII, p. 146) will show that Dr. Feistmantel is mistaken, as this plant was described from the higher Uitenhage series, classed as jurassic, and not from the Karoo beds. I am, to some extent, responsible for the error, as I edited the paper, but I was not then aware of the amount of revision required by Dr. Feistmantel's papers.

[4] Mem. G. S. I., Vol. VII, p. 209.

[5] I regret to be obliged to call attention to the manner in which Dr. Feistmantel has repeatedly mentioned the dates at which these and other fossils were discovered (see especially Rec. G. S. I., Vol. IX, p. 119; Geol. Mag. 1876, p. 489, footnote 12), in order to cast discredit upon myself and others, and to cause it to be believed that these plants were known at a time when I had stated that they were undiscovered. Dr. Feistmantel has omitted to state that the fossils mentioned had been packed away in drawers and boxes, and with, I believe, one exception, had not been identified by any one. Of the exception no notice had appeared in print; the specimen had not been exhibited, and its existence was not known to the Survey generally.

occurrence in great abundance of certain forms, such as *Voltzia* and *Neuropteris*, which had never been noticed in true Damuda rocks, made me suspect that there must be some distinction in the beds, and this view was strengthened by further examination of the flora. In July last Mr. Hughes and I paid a short visit to Karharbári, and by the assistance of Mr. Whitty, Superintendent of the East Indian Railway Co.'s collieries, we were enabled to see much of the ground in a short time. We came to the conclusion that there was an important distinction between the Karharbári coal and that of the Damuda series (both Barákar and Raniganj), the laminated structure so peculiarly characteristic of Damuda coal being almost absent in the Karharbári seams, and, moreover, the conglomeratic beds associated with the Karharbári strata contained subangular fragments, whereas the Barákar pebble beds contain usually none but well-rounded pebbles. The topmost beds in the little field had rather the aspect of Barákars, and some indications appeared to suggest that these beds overlapped the Karharbári group unconformably, but this was not by any means clearly determined. Still, considering the great similarity between all the coal-bearing beds, the distinctions noticed all tended to bear out the separation of the group first suggested by the fossils.

The following is a list of the fossil plants determined by Dr. Feistmantel:—

EQUISETACEÆ—

Vertebraria Indica, very rare.
Schizoneura sp., near *Equisetum Meriani*.

FILICES—

Neuropteris valida.
Gangamopteris cyclopteroides.
G. angustifolia, and two other species of *Gangamopteris*.
Glossopteris decipiens.
G. communis.
Sagenopteris Stoliczkana.

CYCADEACEÆ—

Glossozamites Stoliczkana.
Noeggerathia (*Zamia ?*) *Hislopi*. var.
N. (*Z. ?*), sp.
A peculiar genus, unnamed.

CONIFERÆ—

Voltzia heterophylla.
Albertia, sp.

If this flora be compared with that of the Damuda series quoted at page 134, a very marked difference will be noted, a difference nearly, if not quite, as marked as that which divides the Damudas from the Panchets, and which is considered by Dr. Feistmantel to justify the classification of the former as Bunter, and of the latter as Keuper. Out of four fairly recognized plants in the Panchet beds, one is a Damuda form, but it is the commonest and best preserved of the Panchet species. Of the sixteen species above mentioned only three are known to be found also in the Damudas, *viz.*, *Glossopteris communis*, *Vertebraria Indica* and

Noeggerathia Hislopi; of these, *Vertebraria* is very rare and the *Noeggerathia* differs from the Damuda form, whilst the commonest plants of the Karharbári strata, *Gangamopteris cyclopteroides* and *Neuropteris valida*, are unknown in the Damuda series. Moreover, although the Talchirs are, as a rule, unfossiliferous, a few remains of plants have occasionally been found in them, and all hitherto found have been Karharbári species. It appears, therefore, clear that on palæontological grounds the Karharbári beds must be separated from the Damudas and classed with the Talchirs, and that this distinction is confirmed by differences in mineral character between the Damuda and Karharbári beds. Thus, the lower Gondwánas of Bengal consist of three well-defined sub-divisions, Panchet, Damuda and Talchir, each with a distinct flora. I should add that Mr. Hughes, who has more experience of the Gondwána beds, and especially of the lower Gondwánas, than any other officer of the Geological Survey of India, concurs in the distinction of the Karharbári beds from the Damudas.

There can, at the same time, be no question that there is a distinct and very marked connexion between the flora just cited, and that found in the Bunter group of Europe. The connexion is, on the whole, not so great as that which exists between the plants of the Damuda series and those of the Australian coal measures; but still, if *Voltzia heterophylla* be correctly determined, and I see no reason for doubting the identification, one characteristic Bunter plant is present in the Karharbári beds, and two other Karharbári forms, *Neuropteris valida* and the *Albertia*, appear to be closely allied to the Bunter species. The connexion with the coal measures of Australia (Newcastle and Stony Creek) beds is not, on the whole, so strong as in the Damudas, although *Gangamopteris angustifolia*[1] is a species found in the Newcastle group, and the *Vertebraria*, *Glossopteris* and *Noeggerathia* are closely allied to Australian coal measure forms, so that altogether there is quite as good reason on the evidence of the flora for connecting the Karharbári beds by homotaxis with the Australian beds, classed as palæozoic by the most competent Australian geologists, as with the lower trias of Europe. In the Karharbári beds, too, as in all other Gondwána plant-bearing beds, there are relations to several different European formations. Thus *Equisetum Meriani* to which a Karharbári plant is said to be nearly allied is upper triassic (Keuper), *Sagenopteris* is upper triassic, rhætic and jurassic, being apparently best developed in the oolites; *Glossozamites* is not known below the lias.

It is urged by Dr. Feistmantel[2] that the triassic and mesozoic affinities of the Karharbári plants, belonging to the lowest known flora of the Gondwána system, tend to show that the Karharbári beds are "triassic or at least mesozoic," and he points out the bearing of this fact upon the age of the overlying Damudas. So

[1] This circumstance was not noticed by Dr. Feistmantel, Rec. G. S. I., Vol. IX, p. 138, when he recorded the occurrence of *G. anqusitfolia* at Karharbári. He only mentioned the existence of the species in Victoria "in certainly mesozoic rocks," together "with *Tæniopteris Daintreei*, McCoy, which is characteristic of mesozoic rocks in Queensland." See *ante*, p. 142. *Gangamopteris angustifolia* was originally described as a *Cyclopteris* by McCoy from the Newcastle coal measures, Ann. Mag. Nat. Hist. 1847, Ser. 1, XX, p. 148.

[2] Rec. G. S. I., Vol. X, p. 139.

far as it goes, the argument is fair and fairly urged, but it is not conclusive, and it cuts both ways. Dr. Feistmantel has omitted to note that there is nearly, if not quite as strong a link between the Karharbári beds and the upper coal measures of Australia, and he also forgets that if, as Mr. Clarke and other Australian geologists consider, those upper coal measures are palæozoic, and if fossil plants, like *Voltzia*, are adequate to determine age, the marked palæontological connection between the Damuda and Newcastle beds, more marked than the Bunter affinities of the Karharbári strata, would show the Damudas to be palæozoic, and the Karharbári beds are older than the Damudas.

TALCHIR GROUP.—The close association of the Talchir and Karharbári groups renders it probable that any age which must be assigned to the one must be attributed to the other also. The view appears to be gaining ground rapidly that the connection between permian and trias is greater than was at one time supposed, but there are numerous indications that the permian rocks, containing the poorest of all known faunas of a great geological epoch, and corresponding to the greatest change in animal and vegetable life of which any record has been preserved in the whole palæontological sequence, may have been, as suggested by Professor Ramsay[1] many years ago, a cold period like the Glacial epoch, which has in comparatively recent times affected our planet, but more severe or more prolonged. The evidence of ice-borne boulders in the Talchir beds, as pointed out by my brother, Mr. H. F. Blanford,[2] agrees with similar indications of glacial transport in England and in South Africa, and this clue, however faint, appears to me more promising than the relations of fossil plants.

It would, however, be an omission if I did not call attention to a fact which is of some importance, *viz.*, that in certain permian European floras mesozoic forms are much better represented than palæozoic. Compare, for instance, the list of plants recently described by Heer from Fünfkirchen.[3] This flora comprises the genera *Baiera*, *Voltzia* and *Schizolepis*, all mesozoic types, together with *Ullmania*, which is peculiar to permian beds, there being but one carboniferous genus present.

In formulating the conclusions for which I have endeavoured to show my reasons in the preceding pages, I shall only notice the more important. If Dr. Feistmantel chooses to reply, I beg to point out that these are the essential questions to be decided. It is no answer to me to prove that I have overlooked some paragraph of his, or that I have made a slip about the name or relations of a fossil-plant. I do not pretend to a knowledge of palæo-botany, and I shall probably be shown to have erred in some trifling and secondary matters, as I did before. As no competent critic has hitherto attempted to analyse Dr. Feistmantel's work, and as I believe I have shown that work to be deficient in accuracy, I ask geologists to suspend their judgment as to his conclusions until these have been

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[1] Q. J. G. S., Vol. XI, 1855, p. 198, &c.

[2] Q. J. G. S., 1875, p. 528.

[3] Jahr. K. Ung. Geol. Anst. Vol. V, 1876, quoted in Verh. K. K. Geol. Reichsanst. Wien. 1877, p. 42.

re-examined by a practised palæontologist. My object is gained if I have called attention to the subject, and have defended my old colleagues from Dr. Feistmantel's systematic, if unintentional, tendency to disparage their work.

The conclusions are as follows:—

I. The evidence adduced by Dr. Feistmantel to prove that the Umia beds of Cutch are not upper jurassic would be insufficient, even if it were correct, and the greater portion of it is incorrect. Some of the forms, and amongst these the most important, quoted as evidence of an older age, really confirm Dr. Waagen's view that the beds are highest jurassic, (Tithonian or Portlandian) and the Cutch plant-beds may have been contemporaneous with Wealden, as Dr. Stoliczka considered.

II. The evidence brought forward to prove the Rájmahál beds lias is insufficient to justify the conclusion.

III. No sufficient proof of connection between the Panchet group and the Keuper has been adduced to show that the two are of the same age or related by homotaxis.

IV. The evidence on which the Mángli beds are classed as rhætic and as newer than the Panchets is based upon various mistakes and omissions, whilst the geological evidence upon which the Mángli beds were referred to the Kámthi group (probably older than Panchet) is indisputable, and would suffice to show Dr. Feistmantel's classification of the beds to be erroneous, even if his palæontological data were correct, which they are not.

V. In short, if the affinities of the plant-fossils with those in European rocks were alone regarded, the whole Gondwána system above the Karharbári group would be probably classed as equal to European beds from middle jurassic to rhætic, and it is highly probable that the lower Gondwána Damuda flora would be classed as newer than the upper Gondwána Rájmahál, as indeed it has been, in part at least, by no less authorities than De Zigno and Schimper. On the evidence produced by Dr. Feistmantel himself, both Rájmahâls and Panchets are most closely affined by homotaxis to the same minor European formation, the rhætic, although between the two Indian groups there is the greatest break, both stratigraphical and palæontological, in the whole Gondwána system.

VI. No evidence of any value has been produced to establish the classification of the Damuda series as lower triassic (Bunter); the Damuda flora has far less in common with the Bunter, or with any triassic European flora, than with that of the upper coal measures of Newcastle, &c., in New South Wales, and the mesozoic relations of the Damuda flora, which, after all, are not stronger than the affinities to the Australian upper coal-measure flora, are made out by selecting for comparison plants from various European formations ranging from middle jurassic to lower triassic.

VII. The classification given by Dr. Feistmantel, and stated to be on the authority of Mr Clarke, for the Australian plant-bearing beds, differs materially from all the data published by Mr. Clarke himself, and the union of the Newcastle beds with the Wyanamatta and Hawkesbury rocks instead of with the lower coal measures of Stony Creek, &c., is opposed to all the published evidence, and is

supported by arguments which are either inaccurate or insufficient. No reasons of any value have as yet been assigned for the separation of the Newcastle beds of Australia from the lower coal measures with marine fossils.

VIII. The Karharbári beds must be separated from the Damudas and classed with the Talchirs, and the palæontological distinction from the Damudas is equal to that on the strength of which the Panchets were removed form the Damuda series.

IX. It is just as reasonable to assert that the Damudas and Karharbári beds are carboniferous, because plants, such as *Glossopteris Browniana*, which are proved to be of carboniferous age in Australia, occur in the higher of the Indian groups, as it is to conclude that the whole of the lower Gondwánas are mesozoic because some triassic European forms, such as *Voltzia heterophylla*, are found in the inferior Indian subdivision, but in neither case is the evidence such as to render it wise to come to any positive and unqualified conclusion.

X. That the upper Gondwána may be taken approximately as equivalents of the European jurassic series, and the lower Gondwánas also approximately as triasso-permian, but that anything like close definition of minor horizons in the Gondwána system, or any attempt at establishing the exact correspondence of different groups in India and Europe is premature.

XI. Finally that, as the veteran botanist Alphonse de Condolle has recently pointed out,[1] an attempt to determine geological epochs in countries remote from Europe by fossil plants alone, can only lead to error. I doubt whether terrestrial and fresh-water animals are much more distinctive of geological age than plants.

On a review of the whole subject of the age of the Gondwána system I can only conclude, *first*, that Dr. Feistmantel's attempt to make all the Indian groups fit into the established grooves in the European sequence is a failure; and, *secondly*, that the constant assertion that particular groups belong to distinct European sub-divisions such as lias, Keuper or Bunter, is misleading and unscientific. I believe that the plan pursued by Dr. Oldham and by all the other members of the Indian Geological Survey before Dr. Feistmantel's arrival, of abstaining from any attempt at exact correlation, and of using due caution in suggesting relations of beds, was wiser and more scientific than Dr. Feistmantel's positive assertions as to the age of various Indian rocks.

ON "REMARKS, &c., BY MR. THEOBALD UPON ERRATICS IN THE PUNJAB."

(Records, Geological Survey of India, Vol. X, p. 223.)

Referring to these remarks, I wish to suggest that the ambiguity noticed disappears when the subject is considered from the general point of view in which it presented itself to me.

The erratics of the Punjab were treated of in my paper simply as wandering fragments, some of which could be attributed to ice flotation, and some to other

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[1] Bibliothèque Universelle, Arch. Sci. Phys. Nat. 1875, Vol. LIV, p. 399.

local transporting agency; though there was evidence to connect these also with glacial conditions.

I did not refer these erratics collectively to any particular or post-tertiary glacial period, because some of them presented indications of older glacial conditions. My object was to record the presence of travelled (erratic) masses, and the probable mode of accounting for them, rather than to establish their chronological relations, or advance theories regarding glacial conditions in the Punjab.

I think the origin most lately relied upon for the red granite blocks in the direction of the Salt Range open to uncertainty, both on account of the quantities of these blocks locally present, and of the disintegrating nature of granites generally, but still more, because the conformity of the whole Salt Range series, long since pointed out by Mr. Theobald (Journal, Asiatic Society of Bengal, XXIII, 1854, p. 656) is opposed to the idea that boulders derived from this series below the nummulitic groups could be enclosed in upper members of the same conformable sequence of beds.

The largest of these red granite blocks present no essential difference in their manner of occurrence from that of the other masses supposed to have been ice-borne; they cannot be traced to local disintegration of a boulder bed below the *Obolus* zone, as this conglomerate does not occur in their vicinity, and they greatly exceed in size the blocks of the adjacent cretaceous (?) boulder bed.

Being evidently transported detrital masses, I conceive that the name "erratics" is applicable to the whole of these travelled boulders of the Upper Punjab.[1]

A. B. WYNNE.

January 1878.

[1] Having so defined the word *erratic*, Mr Wynne is, of course, entitled to the benefit of the explanation. According to current usage, an erratic would certainly be understood to imply transport by ice, if not even an appropriation to the familiar glacial period. The essential meaning the word seems fitted to convey is some form of flotation distinct from the ordinary agencies of denudation. As meaning simply a stone not in place, the word would be of very little use.—H. B. M.

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January 15th, 1878.

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CONTENTS.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] **1877.** **[November.**

On the Geology of the Mahanadi Basin and its Vicinity, by V. Ball, M.A., F.G.S., *Geological Survey of India.*

A detailed description of the geology of the extensive area included in the accompanying map, even to the limited extent to which the details of a large portion of it are known, would occupy a very much greater space than is available for the purpose in these pages. In the appendix below will be found a list of papers which describe the coal-fields and certain other parts of the area which have been made the objects of special examination. This account is intended mainly to afford a general sketch of the geological features of those portions of the area of which hitherto there has been no published description whatever. The *data* available for this purpose are derived *firstly*, from manuscript accounts of traverses of the Chhattisgarh basin made by Mr. Medlicott in 1866-67 and by Mr. W. T. Blanford in 1869-70; *secondly*, from my own observations made during the past and previous seasons.

The geographical tract which is coloured geologically on the map embraces an area of about 50,000 square miles, in which the following British Districts and Native States are situated: Cuttack, with portions of the Garjat states of Orissa; Gangpur, and Udaipur and other minor states of the Chutia Nagpur Division; Sambalpur, with portions of its Garjat states of Sonpur, Patna, Borosambar, Phuljhar, Raigarh, and Kalahandi; the Jaipur State under Vizagapatam; the Bustar State under Sironcha; Karial or Kariar, Bindra-Nowagarh, and various other states of the Raipur District. In other words, the area includes portions of the south-west frontier of Bengal, nearly the whole of Orissa, a small portion of the northern frontier of Madras, and a considerable portion of the most eastern districts of the Central Provinces.

Physical Features.—On a map of so small a scale as that which accompanies this report, it would be impossible to effectively delineate the various groups of hills and plateaux, marked and extensive as some of them are. It has therefore been thought better to omit altogether the inadequate hill shading of the original map from which this edition has been produced, thereby securing greater clearness for the names and geological boundaries. But it will be well for the reader to bear in mind that throughout about two-thirds of the whole area broken hilly ground prevails. The first great group of hills to be mentioned forms a section of the Eastern Ghâts stretching in breadth from the neighbourhood of Berhampur, the Chilka Lake, and Cuttack, for a distance of about 130 miles westward to the valley of the Tel River in Kalahandi. North of the Mahanadi, this broad zone continues through Keonjar and Moharbanj, losing itself on the east in the plains of Midnapur and Singhbhum, but maintaining its western branch strongly through Lohardugga and Hazaribagh.

In the Khond Malias, as the zone south of the Mahanadi is called, the peaks are commonly from 2,000 to 3,000 feet high, a few rise to 4,000 feet, and there are some known to exceed 5,000 feet in elevation.

In the neighbourhood of Sambalpur and southwards, in Patna and the western portion of Kalahandi, there is a good deal of tolerably level ground, but here and there isolated peaks and ridges rise from it. To the west of Sambalpur an extensive group of hills is situated on the south bank of the Mahanadi, spreading thence into Phuljhar and Borosambar. To the north-west of Sambalpur is the hilly country of Raigarh and Hingir, which is continued towards Korba and Udaipur. Still further west is the Mandla plateau. In the Raipur states of Karial and Nowagarh, to the south-west of Sambalpur, the country is excessively hilly. First we have, centrically situated as regards the two states, an extensive plateau averaging about 2,500 feet in elevation, and on either side of this plateau, there are numerous ranges and groups of hills, the latter being of more or less foliated metamorphic rocks, while the plateau is formed of horizontal beds of quartzite. To the south of this rises the Jaipur-Bustar plateau, which averages about 1,800 feet in elevation. On the east and south it is bounded by still higher ridges, spurs from the Eastern Ghâts; on the west and also below the southern bounding ridges, it falls by rapid steps to the Godavari valley; on the north-west it slopes off gently towards Raipur, but on the north-east it is bounded by steep scarps, the ghâts through which lead down into the valley of the Tel River, some 1,000 feet below.

The watershed between the rain-basins of the Mahanadi and Godavari traverses the northern portion of this plateau from west to east, and then runs to north-east through the Kalahandi portion of the Eastern Ghâts.

RIVERS.—The principal rivers of our area are the Mahanadi, with its tributaries the Tel, Ebe, Kelu, Mand, and Hasdu, besides many other minor streams too numerous to be mentioned here. The total length of the Mahanadi from its sources in the north-western corner of Jaipur and the neighbouring district of Bustar to the sea is about 500 miles. Of rivers belonging to other basins, but portions of whose courses are included in the accompanying map, the Brahmini on the north-east, the Weingunga on the west, and the Indravati on the south are the principal. The first mentioned is the principal river of its own system, while the two latter are tributaries of the Godavari.

GENERAL GEOLOGY.—So far as is at present known, no series of rocks other than those included in the following list occurs within the limits of this area:—

Alluvium.
Laterite.
Deccan trap and Lameta beds.
Rajmehal series—
  Atgarh group.
? Mahadeva series.
Damuda series—
  Kamthi (Raniganj) group.
  Barakar group.
  Talchir group.
Vindhyan (Karnul) series—
  A. Karial quartzites and sandstones.
  B. Raipur limestones, shales and sandstones.
[Sakoli beds.]
Metamorphic series.

ALLUVIUM.

Under this heading there is little to be said at present. In the published accounts of the coastal districts there will be found some remarks on the subject. In the higher parts of the Mahanadi valley up to the Raipur district, so far as they are known, there are no deposits of alluvium of sufficient extent to constitute alluvial plains as the term is ordinarily understood. Patches of true alluvium of limited extent do occur in the vicinity of the river, and in the Raipur district, which I have not examined; there may possibly be deposits meriting special notice, but in the rocky districts of Sambalpur and Orissa, the alluvium is much mixed with local rock-debris and laterite. In the valley of the Tel, where it traverses Patna and Kalahandi, there is a kunkur-bearing alluvium, sometimes of wide extent, and which attains an importance from the fact of its concealing the rocks. On the Jaipur-Bustar plateau, in the river valleys between the laterite, the alluvium is sometimes of considerable thickness, if not of wide extent. Thus the Indravati sometimes affords sections of 20 feet of a reddish sandy alluvium with no rock appearing beneath.

LATERITE.

Regarding the coastal laterite I only add, to what has already been published on the subject, that in the cuttings through some ridges of laterite on the Khurda road I recently found numerous lenticular masses of dense shaly iron ores which seemed to explain the source from whence considerable accumulations of fragments of similar shale, which I had previously met with, but had hesitated to identify with laterite, had been derived.

The occurrence of laterite in the vicinity and on the rocks of the Raigarh and Hingir coal-field has already been described by me. At that time I had met with no example of high-level laterite in Sambalpur, but during the past season I found several remarkable deposits at high elevations both in that district and others further south. These all occurring in a country into which there is no evidence of the Deccan trap ever having extended seem to be worthy of special description and notice.

The Gandamardan range on the borders of Patna and Borosambar which rises 2,000 feet above the general level of the country, both from its altitude and its flat plateau top, presents a striking appearance when seen from a few miles distance. At first it seemed probable that the structure might be due to flat-capping beds of Vindhyan quartzite, but on examination it was found that the range consisted of steeply inclined garnetiferous and ferruginous gneiss, with a cap of about 100 feet of laterite. The summit is a flat plain with sparse vegetation very similar in many respects to the Main-pât in Sirguja.

On the Karial-Nowagarh plateau which, as is above stated, averages 2,500 feet in elevation, I found some scattered thin patches of laterite, possibly the remnants of a once continuous bed of which, in parts unvisited by me, there may still, perhaps, be better preserved examples. The massive Chaoria hill on the borders of Karial and Kalahandi is not improbably capped with laterite, judging from its flattened appearance as seen from a distance.

In the south-eastern parts of Kalahandi there are a number of *pâts* from 3,000 to 4,000 feet high; of these I was only able to ascend one, Baplaimali, seven miles east of Moulpatna. Its elevation above the sea, according to the Altas Sheet, is 3,587 feet, of which the upper 300 feet is formed of a bed of laterite resting on the up-turned edges of metamorphics. From Baplaimali a good view of a number of other *pâts* is obtained (particularly of Sijimali 4,058 feet). All owe their plateau form to similar laterite caps, which in all probability formed, at one time, a continuous bed throughout a wide area.

In the Jaipur-Bustar plateau, which has an average elevation of about 1,800 feet, laterite, though perhaps of inconsiderable thickness, is very widespread, often completely concealing the underlying rocks over many square miles. In the vicinity of Kotepad and for many miles both to the north and south of it the laterite is especially conspicuous forming numerous low hills, to the terraced alluvial valleys between which the cultivation is restricted.

Raised above the main Jaipur-Bustar region are several minor plateaus; the first of these to be mentioned is one formed of quartzites resting on a metamorphic base and which has an average elevation of about 2,500 feet, like the Karial-Nowagarh plateau. Its position is on the corner of the plateau south of Deobogh. Resting on the quartzites I found, as in the former case, traces of a once continuous bed of laterite. In the Poragar hills again we have a range which rises about 1,200 feet above the main plateau or to a total elevation of about 3,000 feet. The thickness of the laterite cap in this case varies with the irregularity of the underlying surface between from 50 to 100 feet. It would seem then that in this area on all elevations of 2,500 feet and upwards there are traces of laterite, which, it is possible, originally formed portions of a once continuous bed. This may have followed, however, a configuration of the country not very different from that existing at present.*

Many of these laterite caps prove to be most efficient store-houses for water and are consequently not unfrequently the sources of perennial springs; of this the Gandamardan range affords numerous examples.

DECCAN TRAP AND LAMETA BEDS.

In the scarp of the Mandla plateau representatives of the above groups have been observed overlying the Vindhyan rocks of the Chhattísgarh basin. These have not been subjected as yet to detailed examination, and cannot therefore be described in the present account.

RAJMEHAL SERIES.

The sandstones of the Atgarh basin and the fossil plants which have served to determine their position as belonging to the above series have recently been described in these pages†; so far as is certainly known, there is no other deposit of rocks of the same age within our area; but it may be well to record here that I noticed a strong lithological resemblance between certain conglomerates of the Atgarh basin and the highest beds in the Talchir field. The post-Barakar rocks of that area, however, have not yet been thoroughly discriminated.

When at Khurda I was informed, on apparently reliable authority, that sandstones occur some forty miles to the south-west. If such is really the case, they will not improbably prove to be of the same age as the Atgarh rocks.

? MAHADEVA SERIES.

Overlying the rocks of the Barakar group, in the Talchir field, there is a considerable thickness of clays, sandstones, and conglomerates; these, although partially represented by some small outlying patches in the eastern half of the field, are only fully developed in the wild, thinly inhabited, and hilly region of the west, of which no accurate map was available at the time of my visit in 1875. In the original Talchir report these rocks were referred to the then recognised Mahadeva series, and were credited with an estimated thickness of from 1,500 to 2,000 feet; their unconformity with the underlying Barakars was fully

* Near Jashpur, in Chutia Nagpur, there is such a bed which encrusts hills and valleys alike, the effect being to round off angularities, not to fill up valleys to the level of the hill tops.

† Records, 1877, Vol. x, pt. 2, p. 63.

established by the remarkable section at Patrapara, where the lowest bed is seen resting on the denuded edges of a coal seam and some other cases of a more general character. In further confirmation of this view, I met with several cases, more particularly at Tipapani near Landimal on the extreme west of the field, where a coal seam with associated sandstones is unconformably overlaid by a pebbly grit of the upper series.

Overlap unconformity exists on a large scale in the west. Except at Tipapani the rocks underlying these beds are either Talchirs or metamorphics, the edges of the Barakar beds being wholly concealed.

That these rocks belong to two or perhaps even more groups is probable; indeed, in the section of the Ouli River to the south of Patrapara, I thought I could detect some indications of unconformity. We there find a thickness of not less than 600 feet, possibly much more, of yellow and white sandstones with purple clays; these rocks seemed to be much more disturbed than the conglomerates which cap the neighbouring hills.

The conglomerates, of which there is here a thickness of 800 feet, are all more or less ferruginous, and contain quartz pebbles with jaspery ironstone and in some cases nests of white clay. It is possible that these may belong to a distinct group, and their lithological characters suggest a connection with some of the local groups of the upper Gondwana system, more especially with those formerly included in the Mahadeva series.

The above-mentioned yellow sandstones and purple clays are seen in several other parts of the area, more especially two miles east of Kondaikula, where they occur faulted against the Talchirs and are overlaid by ferruginous sandstones. In some respects they resemble Panchet beds of the typical Raniganj area, corresponding thus with some beds of the Kamthi group in the Chanda country. At Intosoro, on a horizon slightly higher than that occupied by these beds, there are sandstones and conglomerates and red clays which seemed to me to be precisely identical with rocks seen in the adjoining field near Hingir. On the whole, in the absence of fossils, it is only possible to form a conjecture as to the affinities of these upper rocks, but the balance of evidence seems to favor the view that, while at least a portion of them may not improbably belong to the same age, *i. e.*, Kamthi, as the rocks of the Hingir group in the adjoining field, the remainder may represent a group of the upper Gondwanas. I have already noted a certain resemblance to exist between the highest conglomerates and some of the Atgarh rocks; this, however, may only be accidental.

DAMUDA SERIES.

Kamthi Group.—In the published account of the Raigarh and Hingir field, a list was given of the fossils obtained in the rocks which were temporarily distinguished as the Hingir group. This list, corrected after further examination by Dr. Feistmantel, includes the following species, which are considered to be quite sufficiently numerous and characteristic to admit of the correlation of the Hingir and Kamthi groups,—thus confirming the conclusion which seemed probable from the lithological and stratigraphical characters:

EQUISETACEÆ.

Schizoneura Gondwanensis (leaves and stalks).
Vertebraria indica, Royle.

FILICES.

Sphenopteris polymorpha.
Pecopteris sp.
Glossopteris indica, Schimp.
Gl. Browniana (?) Bgt.
Gl. angustifolia, Bgt. (with marginal line).
Gl. communis—and another species.

The title Kamthi is in this case preferable to Raniganj, as the lithological character of the rocks is much more closely allied to those of the former than of the latter group. It is unnecessary to add here anything to what has already been stated above as to the occurrence of representatives of this group in the Talchir field.

Barakar Group.—In the accounts of the Talchir, Raigarh-Hingir, and Korba fields will be found nearly all that has been ascertained with regard to the occurrence of rocks belonging to this group. That the Hingir field is connected with that of Korba is known to be the case, but the intervening country has not yet been examined in detail. In view of the possible importance of this field at no very distant period it may perhaps be of service to state that in the area temporarily distinguished as the Udaipur coal-field, the Mand River, and its tributaries the Korja, Samasota, Meria-Kota, Ududha, Saria, Sirni, Kopa, Kharandhoa, Pori, and Baghond, all exhibit sections in which coal and carbonaceous shales are exposed. The known details are too voluminous for insertion here, but it may be stated that there is a fair prospect of good coal being found. The most remarkable section is that afforded by the Samasota River, where a sequence, including eight thick seams, is seen bent into a steep anticlinal with gneiss and Talchirs showing at the broken crest.

Talchir Group.—Since the publication of the sketch describing the Raigarh and Hingir field, the extension of Talchirs in various directions throughout the adjoining area has been ascertained. More particularly worthy of note is the narrow prolongation of the rocks of this group on the south-east of the field into the immediate vicinity of the Talchir field, thus showing that a connection in all probability at one time existed between the two basins. This prolongation extends for about thirty-six miles, from the Ebe to the Boraghat River. There can be little doubt, I think, that it occupies an ancient valley which was in all probability narrower and of a more defined character during the Talchir period than it is at present. It is not probable that the hills on the one side, or the Bamra plateau on the other, were elevated subsequently to the deposit of the Talchir beds, so that this narrow channel may have been the only means of connection between the Talchir basin and that larger area which extends from Sambalpur over so extensive a tract to the north-west.

In my account of the Bisrampur field,* I stated my belief that the boulders which occurred in the Talchir beds there, most probably came from the north, and it is possible that, in this case, the transporting agent may have travelled from the north-west. At the same time I may say that I did not see anything about the character of the gneiss boulders in the Talchir field to justify the opinion put forward in the Talchir report to the effect that they had probably come from a long distance. So far as I could see, and in consequence of the above opinion I gave particular attention to the subject, the boulder beds of the Talchir field do not contain any materials which might not have been derived from the very great variety of coarse and fine-grained gneisses which are to be found in the neighbouring areas. In the Bisrampur area where boulders of Vindhyan quartzite occur, the case is, of course, quite different. In this connecting strip, except towards the Ebe end, I saw no traces of a boulder bed, the rocks being all shales and sandstones. They seem to be little disturbed from their original position, but at the nearest point to the Talchir field they are cut off by a fault which is not improbably a continuation of the main bounding fault of that field.

During the examination of the older rocks various thin outlying deposits of Talchir beds have been met, not only in the vicinity of the coal-field, but also far to the south of the Mahanadi. In the vicinity of the field, besides the outlier already mentioned near the villages of Tuldi and Terda,† another has been found on the east bank of the Ebe between

* Records, Vol. VI, p. 28.

† Records, Vol. VIII, p. 104.

Ishtapali and Jogipali. Its precise area is somewhat doubtful owing to the way in which it is covered by superficial deposits. Another of small extent exists in the interval between the main Talchir area at Bolunda and the outlier at Terda. South of the Mahanadi and opposite to its junction with the Ebe, just close to the village of Rasem, is a third. It is about half a square mile in extent. Sandstones, shales, and the boulder bed are all represented within these limits.

In the Pal-jor, a small tributary of the Ong River, to the east of the village of Ganislot, the section discloses the existence of a small basin occupied by Talchirs. The rocks consist of sandstones, shales, and a well developed boulder bed with rolling bedding. On the south they seem to rest directly on the gneiss, but on the north the character of the boundary is uncertain owing to the superficial covering. The exact area has not yet been ascertained; it probably does not exceed three square miles. Still further south, in the bed of the Tel River east of the village of Tanigaon, Talchir sandstones are exposed under the bank. On the south they are cut off by gneiss, but how far they may extend to the north-east, up the valley of the Ebe, is not known. Other localities where rocks of this group are reported to exist are at Keutasingha in Patna and Baisasankar in Boad.

VINDHYAN SERIES.

General lithological resemblance and the relations with other formations are the sole *data* available for correlating the series of azoic sandstones, limestones and shales of the Chhattisgarh and neighbouring areas with the Vindhyan series of Northern India. Already, in a general way, the Karnul series of Madras has been identified with the lower Vindhyan series; but even though the details of the sequence in both are well known it has been impossible hitherto to establish even an approximate correlation of horizons. Such being the case where the rocks have been fully examined, it will be readily understood that with rocks the sequence of which in the wide area of Chhattisgarh is at present a matter of some doubt, no attempt at detailed correlation can be usefully attempted.

Until some complete standard sections have been locally established, comparison with other areas cannot be of much aid in the elucidation of the history of these rocks. But some allusion to the rocks of the same age in the Chanda and Godavari valley districts may become necessary.

Apparently two great groups of these rocks exist, one (A) consisting of a thickness of upwards of 1,500 feet of quartzites, sandstones, and conglomerates resting on shales which latter, in some sections, appear to have been considerably disturbed before the deposition of the upper beds. The relations between the two seem to be in many respects similar to those existing between the upper and lower Vindhyans of the Vindhyan range. What the relations may be which exist between these shales and those of the second group is at present not absolutely known, as no section hitherto examined contains both groups of rocks in their full development; but from their lithological characters and some other considerations to be mentioned hereafter, I am strongly inclined to believe that these shales belong to the second group which seems to be the elder of the two. This second group (B) consists of limestones, shales, and sandstones. The existence of these sandstones interbedded with, and in some cases underlying, the shales and limestones, has been the principal cause of the difficulty which has been experienced in assigning the rocks to two groups, and also establishing the relative position of these groups in the geological sequence. In the following pages, however, sections will be described where sandstones occur sometimes underlying, sometimes interbedded with, limestones and shales; and, on the other hand, sections of what are considered to constitute an upper group, in which there is an unbroken thickness of upwards of 1,500 feet of quartzites, sandstones, and conglomerates resting

upon shales as has been above mentioned. In regarding the latter as the younger group my views are, I believe, in accordance with Mr. Hughes' opinion in reference to the similar and very similarly circumstanced rocks of the Chanda district. Before proceeding to describe the physical relations of these rocks, so far as they have been examined, it only remains to point out the geographical areas which they occupy. The largest and most important area is that of the Chhattisgarh basin, the northern boundary of which stretches in a north-west direction from the neighbourhood of Sambalpur, passing Padampur, Raigarh, Bilaspur, and Ratanpur up to the base of the Mandla plateau. Southwards from this with a very irregular eastern boundary, these rocks spread to unknown limits beyond the Raipur district. It is possible indeed that they will be found to be continuous with the Bustar-Jaipur area to be mentioned below. The second area forms a considerable plateau which belongs partly to Nowagarh and partly to Karial. The third is also a plateau, and is situated on the north of the Jaipur district. To the south of this is the fourth area, which is included in both the Jaipur and Bustar districts. Besides these there are rocks of this age near Nowagaon and Ahiri to the south-east of Bhandara.

Group A.—Sandstones, Quartzites, and Conglomerates.

Although it is probable that members of this group will be found in the first area, they have not yet been separated in the extraordinarily crushed and disturbed sections of the northern boundary, where there are, especially in the Barapahar hills, rocks lithologically similar to those about to be described. The standard sections, than which no better are likely to be found, are met with in the Nowagarh-Karial plateau. This plateau is of an irregular oval shape, with the major axis running north and south. The area exceeds 750 square miles. The general elevation averages probably about 1,500 feet above the surrounding country, or say 2,500 feet above the sea. Certain peaks are, however, over 3,000 feet high. With a few local exceptions, the quartzites which form this plateau dip inwards away from the gneiss.* On the west, in Nowagarh, the nature of the junction between these rocks and the metamorphics is very admirably illustrated in a series of peculiarly clear sections. In the best of these, in the Japen River at Doarpur and in the Pairi River near Nangabahar, the quartzites are seen at the level of the bed of the river resting directly on the denuded and irregular surface of the granitic gneiss. In the former section the bottom bed of quartzites has in places been eroded, and shows the bare granitic rock within the main line of the boundary. In the latter section the quartzite boundary has, in the bed of the river, been cut back for several hundred yards, and the granite is seen, both on the banks and at the base of a waterfall 20 feet high, underlying the quartzites, the lowest beds of which fill up the inequalities of the surface of the granite. Both to the north and south of the Pairi section, there are outlying caps of quartzite resting on several small granite hills which are situated within from a quarter of a mile to a mile to the west of the main line of boundary.

In these sections, especially in the first mentioned, we find traces of a black carbonaceous shaly bed in association with the quartzites. This bed is of importance, as marking a definite horizon, and will be referred to on a future page.

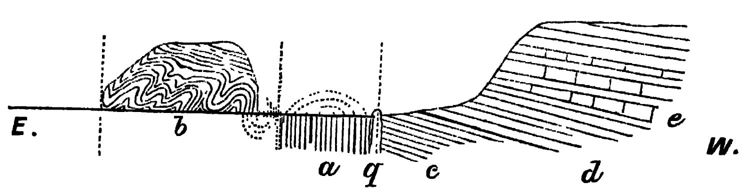
From the Maliva hill round the northern end of the plateau to Tarnot, and thence to Borkot, we do not find exactly the same relation existing, but the boundary is still a natural one. The original bounding rim of crystalline rocks which limited the basin of deposit is here in a great measure still conserved, and the elevation at which the line of junction occurs constantly varies, thus affording evidence of internal overlap between the beds of quartzite along the margins of deposit. In some instances the granite is capped by the higher beds

* A glance at the Atlas Sheet will show the basin-like character of the top of this plateau. The numerous rivers emerge from it over falls and through deeply cut gorges by which their waters reach the level of the surrounding country.

of plateau quartzite at an elevation of 900 feet above the base, and from this amount downwards the levels constantly change, different members of the sequence thus occurring locally as the bottom beds of the group. Of course sections of these rocks in the scarped sides of the plateau are not rare, though many of them are difficult of access. The principal one examined was in the gorge of the Jonk River between Maragura and Jumlagor.

Jumlagor is at the head of a waterfall which is probably 300 feet high. Its elevation is about 850 feet above Maragura, and as the beds forming the plateau are slightly inclined southwards, the ascent traverses the edges of a thickness of beds somewhat in excess of that amount. These beds consist almost exclusively of quartzites exhibiting various degrees of vitrification; the exceptions are beds of conglomerate consisting of small, sometimes minute, quartz pebbles firmly compacted together in a thin matrix. No shaly beds whatever were detected as occurring with these quartzites, which are mostly rather thin-bedded, the distinct layers rarely exceeding 3 feet in thickness. As to the character of the beds of the remainder of this group, *i. e.*, those above the horizon of the Jumlagor beds, I was not able to examine them in detail, but they seem, so far as is known, to be very similar in character to the lower portion. In the internal valley of the Girna River to the south-west of Tarnot, we find dipping under the quartzites of the plateau a group of shales having an extraordinary resemblance to Talchirs, and showing an amount of disturbance which is not shared in by the quartzites of the surrounding ranges. No trace of these rocks was found at the base of the already described western quartzite natural boundary, but on the east they occur in all the deep internal valleys within the outer bounding range of quartzite, and are also found in vertical, apparently faulted, contact with the gneiss close to the eastern base of the horizontal beds which form a small outlying plateau to the east of Tarnot. It will perhaps be sufficient for present purposes to describe two sections which exhibit the relations existing between these beds and the quartzites. These sections are afforded by the gorges of the Under and Udet Rivers.

In the accompanying sketch of the former is represented the relations of the beds as they are understood by me, but the central part of the section is by no means clearly exposed, and may possibly admit of another explanation. The observed facts are as follow :—



Section in the Under River. Horz.: Scale 1 inch = 1 mile.

The section of the outer range is very clearly exhibited on the southern bank of the river. The beds marked (*b*) consist of quartzites with very thin interlamination of red and green clays, these clays being more especially abundant in the central portion of the thickness exposed. The lowest bed seen outside is a quartzite which is much indurated, and which is bent abruptly to the vertical, forming, at least for a short distance, a steep outer face on the hill. After a series of rapid contortions, which do not show, to the same extent, in the beds on the top of the hill, these lower and central beds dip suddenly vertically downwards and do not reappear. Probably, if the rocks were uncovered and visible, we should

find that they are brought up by another contortion, as is represented by the dotted lines. A short distance further up the bed of the river we come upon vertical beds of red shales (*a*), which, if not related as represented, would be younger than the quartzites (*b*), a view untenable from the relations found to exist between them elsewhere. That the quartzites (*b*) are bounded by an external fault is most probable. Unfortunately, no contact with the metamorphics is seen, there being no outcrops in the bed of the river for several miles to the east. Both here and all along the boundary of the plateau area from hence southwards to within a short distance of the Udet, the disturbance and constantly varying character of the beds could scarcely be explained by mere lateral crushing. To the north it is possible that a ridge of fault-rock in the metamorphics at Tarnot may mark the continuation of the line of fracture. Regarding the second fault represented, the shortness of the interval between the quartzites (*b*) and the shales (*a*) argues, I think, against the possibility of the whole of the former being brought up by a contortion, and therefore it seems probable that the lower members are cut off by a fault, and that the red shales (*a*), as represented, have been thrust into vertical contact with the quartzites of the central part of the sequence. Passing the red shales (*a*) we come upon a wall-like ridge of pseudomorphic quartz (fault-rock) (*q*) which strikes to about 20° east of north, 20° west of south. Beyond it there are thin-bedded quartzites, shales (*c*), and a black carbonaceous sandy layer (*d*) dipping to from 5° to 10° to west and west-north-west. Overlying these conformably are the saccharine and vitreous quartzites, &c., which form the main mass of the plateau. That this run of fault-rock marks a line of disturbance there can, I think, be little doubt, the more particularly as the thin quartzites (*c*) and shaly beds associated with the carbonaceous layer appear to represent a portion of the contorted beds (*b*) of the outer range. Further, with reference to both this and the previously mentioned fault, evidences of a pair of diverging faults are found for many miles amongst the crushed and disturbed beds in the internal valley to the south. They are also indicated by lines of a breccia abounding with brown hæmatite,* and on one of them is situated a *Hot spring* near Kotagarh. Taken alone, this section, due allowance being made for marginal crushing and fractures, would not be sufficient to prove original unconformity between the beds *c*, *d*, *e*, and the red shales (*a*); but it must be remembered that in other localities where the lower beds are seen in a very disturbed condition close to the base of horizontal quartzites, similar explanation of the relations of the beds by pairs of faults cannot be given.

In the Udet River from Boidelpur westwards there is a section of the lower shales. The first beds seen are red and grey shales, with one bed of quartzite resting on them and dipping at, apparently *under*, granitic gneiss at an angle of 45°. In the northern bank of the river the granite, for about a foot, seems actually to overhang the bed of quartzite. This appearance may be due either to original deposition under an overhanging ledge or to the effects of a horizontal thrust from the west, probably the latter, as the bounding fault can scarcely have died out again before reaching this point.

Elsewhere I have noted cases of similar beds dipping at the boundary. The river between Boidelpur and Tonkulmal exhibits a nearly continuous section of grey, red, and black shales, with, in places, much infiltrated iron. Besides the above-mentioned bed, no quartzites appear in the bed of the river. The dips are for the most part low to east, east-south-east, south-east. In the hilly country to the south there are quartzites which, at the boundary between Koirpodor and Phulchi, locally dip 80° to east and south-east. Elsewhere they flatten and become horizontal. It seems scarcely probable that they rest conformably on the red and grey shales, but no actual junctions were found.

Finally, it has been established that these shales are older than the quartzites; that they are clearly overlapped is apparent from the sections on the west, in which they do not appear.

* Near Bandi, Kootagarh, and Kudapani respectively.

That they are unconformably overlaid is probable from the amount of disturbance they exhibit as compared with the overlying quartzites. In their lithological characters they correspond with those of some of the rocks of group (*B*) of the Chhattisgarh basin and Jaipur-Bustar area. This resemblance, so far as it is of value, is in favor of the view that the quartzites of group (*A*) are younger than the limestones, &c., of group (*B*). But in addition to this, we have the physical evidence afforded by the fact that the Karial-Nowagarh plateau quartzites occur in their original undisturbed position at a much higher elevation, 1,500 to 2,000 feet above the limestones of the Chhattisgarh basin, the nearest points on the *natural* boundaries of both areas being only a few miles distant.

Again, in the Jaipur-Bustar area about to be described, we have quartzites the base of which is at an elevation of 700 feet above the level of the rocks of group (*B*).

Great faulting in the intervals between the localities where these beds occur might serve to explain these differences of level under the supposition that the quartzites were older than the limestones, &c. But in the absence of the slightest evidence for faulting, the more legitimate conclusion to be drawn seems to be that the quartzites of group (*A*) are really younger than the limestones, &c., of group (*B*).

JAIPUR AREA.—The only other locality in which rocks of the same age as the Karial quartzites have as yet been identified is situated on the north-east corner of the Jaipur plateau to the south of Deobogh. There they rest upon a pedestal of crystalline rocks which is from 600 to 700 feet above the main Jaipur-Bustar plateau, and therefore corresponds in general elevation with that of Karial-Nowagarh. This small plateau, which extends over about 150 square miles, has been much broken up by river gorges in which the crystalline rocks underlying the thin quartzites are at various elevations laid bare. The quartzites, so far as they have been examined, are lithologically similar to the upper beds of the neighbouring Karial-Nowagarh plateau, with which, indeed, it is most probable they were at one time continuous.

Group B.—Limestones, Shales, and Sandstones.

The known limits of the Chhattisgarh basin, the principal area in which rocks of this group occur, have already been roughly indicated. It will only be possible to give here a very brief sketch of what is known of the rocks.

Commencing description from the most eastern point where these rocks occur, and not pausing more than just to mention the fact of the occurrence of several small outliers, we find in the Barapahar hills, a few miles to the west of Sambalpur, an accumulation of shales, sandstones, and quartzites whose relations, not only externally to the metamorphic series, but internally with one another, is of a complicated nature, and which can only be understood after much more time has been devoted to their examination than has hitherto been possible.

This indeed is a region of special disturbance, and one which, when the detailed examination is taken up, would probably be most profitably reserved for the conclusion when standard sections had elsewhere been ascertained. The boundary of this area runs north-westwards, crossing the Mahanadi at Padampur. In some places, massive vitreous quartzites, with bedding obscure or completely obliterated, while in others shales, with occasionally vertical bedding, occur in contact with the metamorphics. Occasionally these rocks dip *towards* the boundary at high angles, a state of things produced probably by intense lateral pressure combined with faulting. In some cases these dips appear to be *reversed*, being produced by the folding over of the beds on themselves.

The opposing edges of the two formations, as exhibited in the Squi River and also in the Mahanadi at Padampur, pretty clearly show that a fault has contributed to produce the relations now existing. In the latter section, the line of fracture traverses the lines of strike

of both series of beds obliquely, and in consequence we find in one place the edges of beds of quartzite shales and limestones in opposition to beds of metamorphic rocks, though no actual contact is exposed.

In the neighbourhood of Padampur a considerable section of these rocks is exposed, the lowest occurring in the vicinity of Dungri, where the beds form a partial qua-qua versal dome which is of a very marked character on the north-west of the hills.

The lowest beds seen are sandstones forming a central dome. Resting on these in the valley, there is an unknown thickness of limestones which dip 15° west under the sandstones forming the outer ridge of the hills, where the river changes its course from north to east. Above these sandstones again, in the north to south reach, there is another bed of limestone which is exposed under the east bank; overlying this are red sandy beds which are exposed near the mouth of the Kailo River. Thence up to Padampur, the section in the Mahanadi gives an almost unbroken sequence of shaly red sandstones, &c., with about 100 feet of an externally dove-coloured limestone with numerous veins of calcspar. The dips at first to west turn to north, and close to Padampur are inclined to north-east. At Padampur there is yet another zone of limestone which contains some strings of galena. Under the town the dips are much disturbed, and the rocks are abruptly cut off at the boundary. From the preceding it follows that there are in this section, which includes a thickness of perhaps as much as 3,500 feet of rocks, four distinct zones of limestone, each of which differs lithologically from the others. To the north-west from this the boundary runs with that of the Raigarh-Hingir coal-field, metamorphic rocks being occasionally interpolated.

Mr. Medlicott, in his manuscript report of his traverses of the Chhattisgarh area, has given an account of the sections examined by him along the northern, eastern, south-eastern, and western boundaries from the Mandla plateau to Sambalpur. The principal forms of rocks observed were 1*st*, strong-bedded quartzite sandstones, "often coarse and rusty, often pure and fine;" 2*nd*, "massive, fine, homogeneous clays often affecting a flat nodular structure resembling somewhat the splintery clays of the Talchirs. There are also finely laminated silicious shales; these are often calcareous, and pass insensibly into finely laminated silicious limestones in the manner so common with some of the lower Vindhyan bands of the Son and of Bundelkhand. These shales seem also connected with fine flaky beds very hard and compact (porcellanic) on a fresh fracture, but betraying their flakiness by weathering. These beds, too, find their exact analogues in the lower Vindhyans;" 3*rd*, limestone.—"Limestone is perhaps the commonest rock at the surface all over the plains of Chhattisgarh. It is seldom a pure homogeneous rock, being often flaky and earthy or silicious. Often also the silicious matter is distributed in strings or in irregular concentric concretions.

"It would seem to be only in the most general way that these several rocks observe any order of position. I think all three types may be observed as bottom rock resting upon the metamorphics. But there is a decided preponderance of the sandstones in this position. It would seem that the sandstone never attains a considerable thickness, save at or near the base of the series.

"This variability in the deposits is also a point of similarity with the lower Vindhyans and with rocks described by Mr. W. Blanford in the Godavari area.

"As the most frequent bottom-rock, the sandstones are seldom seen in force except near the boundary, but they are nowhere so much developed as in the south-east, resting on the gneiss of the Jonk area and of Sambalpur, and forming ridges running northwards from that area."

On the south-east boundary only did Mr. Medlicott meet with a "distinct case of simple unaltered superposition." Close to the east of Arang, the shaly, flaggy, dark, silicious limestone shows with a steady inclination of 3° to 4° westward, and on the rising ground to eastwards, the strong-bedded sandstones pass up from beneath the limestone and shales to form a low range of hills. These hills present a gentle slope to the west, and are scarped along the eastern face, in which the junction can be admirably seen of the massive sandstone resting on coarse granitoid gneiss and largely made up of its debris. This debris is not "coarse and water-worn, but gravelly and still undecomposed." Further south in the Pairi River section, I met with the continuation of this marginal bed of sandstones, but I saw no clear indication there that they passed under the limestones. Indeed, from the absence of any distinct dip of the sandstones and the lower level at which the limestones occur, it seemed to me possible that these sandstones might be the marginal remnant of an overlapping bed; but there was, it must be admitted, an interval quite sufficient between the localities where these rocks were respectively exhibited to permit of the sandstones dipping below. Mr. Medlicott has generalised his observations in reference to this and other sections in the following words: "The topmost strata are almost confined to the low grounds where they show the minimum of disturbance, while the bottom bands rise along the boundary and are often much modified by contortion and compression. One has to seek far and wide for proof of the two being really continuous."

The sections on the western boundary present a general resemblance to those of the northern, but the thickness of shales exposed there is greater, and the general character is of course much modified by the presence of overlying basalt.' At Warraband, on the Raipur and Nagpur road, the Vindhyans are separated from the crystalline rocks by a bifurcating ridge of quartz, the branches of which strike to north 10° east and north 30° east; the latter possibly marks the position of a fault. East of it are rocks identified by Mr. Blanford (*MS.*) with the Vindhyan sandstones of the Godavari area—"They are hard purplish grits and appear to dip to the eastward at an angle of 10°, but this is far from clear. They continue for a mile or more, apparently with the same inclination, but they are by no means well exposed, and a little beyond (east of) Warraband all the rocks become concealed by soil." "Limestones are exposed in the Mula River, about six miles beyond (east of) Warraband. They are unmistakably identical with the Pem limestones, and they dip at a low angle to east-north-east. A mile further the red Pem shales are seen nearly horizontal, and they continue as far as Nandgaon."

With regard to the general section of lower Vindhyans in Chhattisgarh, Mr. Blanford has written: "Apparently the section of the lower Vindhyans of Chhattisgarh closely resembles that in the Pem Gunga valley. Massive sandstone at the base, then limestone, above shale, upon this apparently rest alternations of thinly-bedded sandstone and limestone. It should, however, be remembered that the rocks are only seen in the Chhattisgarh plains at distant intervals, and that but a very imperfect notion of the section can be obtained without far more careful examination than it has hitherto been possible to give to the ground. Still the general section east of Raipur so exactly represent that to the west that the main sequence, agreeing as it does with that in the Pem Gunga valley, may fairly be considered as correctly ascertained."

Could it be shown that these quartzite sandstones are in the Chhattisgarh area representative of the great thickness of beds in Karial and Nowagarh, then the latter would have in all probability to be regarded as younger than the limestones; but I have already shown that these indubitably rest upon shales—possibly unconformably—whose lithological resemblance more particularly to the Talchir-like shales described by Mr. Medlicott is still stronger than is that to be found between the quartzite sandstones of the two areas.

JAIPUR-BUSTAR AREA.—On the Jaipur-Bustar plateau we find a group of limestones, shales and quartzite-sandstones of precisely similar character to those of the Chhattisgarh basin. It is not improbable that the two areas will be found to be continuous, but the intervening country has not yet been traversed.

In Jaipur the rocks of this group, although they occupy a by no means inconsiderable area, are, for the most part, so much concealed by superficial deposits that it is quite impossible to give anything like a connected section of them. But a few detached points, marking the boundaries, have as yet been fixed; from these, however, it would seem that the limestones and shales occupy a truncated triangular area, which, commencing near the Naorungpur and Jaipur road, spreads westwards into Bustar. It would be useless with the imperfect data at present available to attempt a discussion in these pages either as to the sequence of the rocks or the nature of their boundaries; but from what I saw, I think it not improbable that both north and south boundaries may ultimately prove to be faulted. Certainly I did not see at any of the points examined any clear case of superposition. At Korenga there are sandy quartzites with a dip of 35° to south-west, or away from the crystallines. They are of inconsiderable thickness, possibly the dip carries them under some red calcareous sandy flags which are exposed near Jobra, but the interval between the outcrops is considerable. It is not improbable that the river beds which cross the boundary near Korenga may disclose the nature of the junction.

To the south of Kotepad there is a fairly continuous section of impure grey limestones with red shales, exposed in the bed of the Joura River above its junction with the Ambabal. The limestones dip south 35°. The overlying shales are in places a good deal contorted, but south-east 40° represents the principal direction. Lithologically, these rocks correspond closely with certain beds of the Chhattisgarh basin, as, for example, with some of those above described in the Mahanadi section at Padampur.

In Bustar the rocks seen consisted chiefly of red flaggy nearly horizontal beds of sandy clays; these, at Karinji, are seen overlying quartzite sandstones of, apparently, no great thickness. These beds are in places calcareous, and occasionally impure red limestones occur. I was unable to visit the Chiterkot falls on the Indravati, but specimens brought thence included fragments of vitreous quartzite, and a black shale, like that found at the base of the Karial quartzites.

The examination of the gorge below this fall may not improbably shed a considerable light upon the relations of the beds which constitute the plateau.

From the neighbourhood of Chitapur, which is about sixteen miles to the south-west of Jugdalpur, I received a specimen of a limestone of very similar character to the very pure form already mentioned as occurring at Dongri near Padampur. It is an opaque greyish-white rock with a splintery fracture. A similar rock is found at Korokpur, sixteen miles to south-east of Jugdalpur. Lime is manufactured from this rock in preference to all the other varieties.

SAKOLI BEDS.

West of Gortalou on the Raipur and Nagpur road there is a section of trap-like rocks, the structural relation of which to other rocks in their vicinity is very obscure. Within the area occupied by them we find also ridges of (? pseudomorphic) quartz-rock apparently similar in character to some found in the adjoining metamorphic areas, where they are, in some instances at least, metalliferous, as will be mentioned further on. One of these ridges is found to the south of the Bagh-nadi bungalow, strike 10° west of north. Before it is reached, however, between the 94th and 95th milestones, there is a bed of quartzose pebble conglomerate which cannot at present be referred to any known formation. The pebbles are mostly of white quartz and 2 to 3 inches in diameter. A similar

rock, not improbably the same bed, is met with between the 90th and 89th milestones, and again between the 85th and 84th. In all cases the dip is nearly vertical, and the recurrence of the bed may be due to contortion folds. Trap is seen in the intervals. It is a dense dark-green rock, and save at Burbruj, was nowhere observed to be amygdaloidal. Near the 82nd milestone, the road-cutting exhibits sandy grits and shales alternating with trap in vertical beds. These imperfect observations were made by me under the very disadvantageous circumstances connected with travelling along a road crowded with traffic in the middle of May, and at the rate of fifteen miles a day. They do not, however, constitute the first or only record of this singular group of rocks. They are mentioned by Mr. W. T. Blanford in the manuscript notes of his march from Chanda through the Chhattisgarh country. He writes: "To the east and south of Pallandur* are some hills composed of a singular series of formations which have a very sedimentary appearance, but are, in all probability, decomposed volcanic or trappean rocks of ancient date which it is difficult to separate from the metamorphics, although their mineral character is very unlike that of the hornblend rocks, diorite and syenite, usually found associated with the great crystalline formation of India. In the hills east of Chisgarh, the rock appears to be mainly composed of quartz and felspar. It is pink in colour; associated with it are some red ferruginous shale beds, all evidently much altered as if by weathering. In the Garwai Nadi metamorphics occur, the peculiar trappean (?) rocks forming apparently a hill range along the south bank for some distance, but the road north of the river crosses a mass of the ferruginous shaly rock in one place, and then, about two miles before reaching Chisgarh, ascends a high ghât over crystalline and compact trap, probably the undecomposed form of the rock already specified. At the base of the ascent are some earthy slaty beds, very similar to those seen in the lower Vindhyan sandstones at Nowagaon Tank, but rather more schistose. Some of the traps are amygdaloidal, but I do not think there is any probability of their belonging to any overlying formation; and although it is possible that they belong to a newer series than the metamorphics, they must, I think, until the country is more closely examined, be classed with those rocks."

Mr. Blanford also mentions the occurrence of conglomerates similar to those already described, one of his localities, "two or three miles east of the Bagh Nadi," being probably identical with one of those given above.

METAMORPHIC SERIES.

In the wide area under description, the bedded metamorphic rocks very possibly all owe their crystalline character to one and the same period of metamorphism; but that they all are the result of the metamorphism of but one uniform series of rocks is most improbable.

Not only is it possible, to a great extent, to separate these rocks into groups, distinguished by marked lithological characters, but if, as seems probable, the bedding structure now seen really corresponds to the original sedimentary sequence, it is scarcely possible to conceive that subsequent disturbance could have produced the relations which are sometimes found to exist between adjacent sections. On the other hand, such relations might very readily be explained by supposing the existence of original unconformity between the beds. By some authorities it is maintained that these so-called beds are due to foliation on the large scale; but when the occurrence in immediate juxtaposition of beds of utterly different composition is exemplified by the cases of limestones next to schists and conglomeritic schists in contact with crystalline gneisses, and when the cases afforded by the less modified sub-metamorphic rocks are all taken into consideration, the conclusion, that the beds now existing

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* To the south-west of the road section described above.

truly represent the order and position of an original sequence seems, to be the more legitimate one to draw.

The limits available for the purpose here will admit of only a very brief sketch of the more prominent features of these rocks.

VALLEY OF THE MAHANADI, FROM CUTTACK TO SONPUR.—Passing westward from the sandstones of the Atgarh basin, along the south bank of the Mahanadi, the rocks seen consist chiefly of varieties of garnetiferous gneiss. These are best exhibited in the Barmul Pass, where the river runs almost due north-west south-east between two sugar-loaf peaked ridges, the dip of the beds being from 40° to 80° to north-east.

Towards Horbonga, and thence to Sonpur, the rocks consist chiefly of coarse porphyritic gneiss, which occasionally shows strikes varying from north-west to west-north-west; but not uncommonly the rock is massive, and exhibits no distinct bedding or foliation.

VALLEY OF THE MAHANADI, FROM SONPUR TO SAMBALPUR.—Between Sonpur and Binka the rocks, where seen, consist, for the most part, of granite, with quartz veins. In the Ong River there are some hornblendic gneisses, and further on, fine-grained bacillary gneisses and quartzites. Close to Binka there is a schistose quartzite, similar to a rock seen in the station of Sambalpur. Its strike is east 35° north, west 35° south, with a dip of 50° to 35° south of east. Further north, at Turam, in the bed of the Mahanadi, there are schistose and granitic gneisses, striking north-north-east, with a dip of 60° to east-south-east: these form the long hill ridges on the eastern bank of the river.

In and near the station of Sambalpur, the rocks are chiefly granitic and porphyritic gneisses, associated with which is a band of quartz schist. The beds are, for the most part, vertical, but in places there appears to be a dip towards the east-south-east. The strike varies from 10° to 30° east of north. A point about three miles east of Sambalpur seems to be the centre of a great synclinal basin, the rocks on all sides consisting of granitic and syenitic gneisses, with schistose and shaly alternations.

AREA NORTH OF SAMBALPUR.—Ten miles north of Sambalpur is the Kudderbuga range, formed chiefly of quartzites, which are much more strongly developed in the western half of the range than in the eastern.

In the Bonum River, south of Katikela, the section exposes a metamorphic conglomerate. The matrix is quite schistose, but very dense and hard, and it includes rounded pebbles of white quartz. The same rock occurs three and half miles further north, in the bed of the Sumpai, south of Dulki. Lodes of brown hæmatite (altered magnetite) occur in the rocks near Kudderbuga, more particularly to north of Rarimoul. The principal one seen there consists of a quartz-iron breccia, which strikes, with the surrounding rocks, to about west 15° north. The ore used by the natives is taken from the washed debris of this lode. Close to Talpuchia there is a small hill of fault rock and *gossan*. It is possible that a metallic lode may exist there. Pebbles of carbonate of lead were found in the alluvium about a mile and a half to the south.

The last section in this tract of country which there is space to notice here, is that afforded by the (Gangpur) Sumpai, a tributary of the Ebe. Close to Kujerma the bed of the river discloses a thickness of 50 to 60 feet of blue limestone, dip 40° south-south-east. Underneath these are somewhat sandy quartzites, and the two rocks taken together are not unlike the Vindhyans seen near Padampur. Nearer the village, however, these rocks appear to be conformable to and dip under granitic gneisses, which are in close proximity; but no actual junction is seen. A portion of the limestone is of inferior quality, containing tremolite: but much of it is a strong pure rock, which ought to prove valuable, should occasion arise for its employment.

The same limestone is seen near the junction of the Sumpai with the Ebe, where it occurs in horizontal beds, abutting against a vein of coarse granite.

AREA IN THE MAHANADI VALLEY TO THE NORTH-WEST OF SAMBALPUR.—In this area, which is bounded on the north by the coal-field and on the south by the Vindhyan rocks, there is a considerable variety of both schistose and granitic beds: of the latter, the most common is a granular-looking, but really finely porphyritic variety. But, perhaps, the leading feature presented by these rocks, especially in the area to west of the Ebe, is due to the presence of several strongly-marked bands of quartzite, which form a series of ridges, with an almost constant strike to north-west south-east. The most remarkable of these is the one which culminates in the Sunari H. S. peak (1,549 feet). The rocks occurring in this hill are protogine granites, covered by the quartzites and blue-and-red sandy schists, which dip to north-east at about 80°. The schistose beds have a decidedly sub-metamorphic aspect, but cannot be separated from the gneissose rocks. On the same line of strike occurs the long ridge of quartzites, which bounds the coal field north of Kudderbuga. There are several parallel ridges to the above, with vertical bedding, which traverse the metamorphic area north of the Mahanadi. In some places these quartzites are quite vitreous; in others, distinctly granular, and not readily to be distinguished lithologically from certain beds of the Vindhyans.

AREA SOUTH OF THE MAHANADI (DUKIN-TIR).—The rocks of this area, so far as they have been examined, consist principally of granitic gneisses, which, however, present no very leading or prominent features, save that in the neighbourhood of Barpali, and perhaps elsewhere, trap-dykes occur in some abundance. Generally speaking, traces of volcanic action in the region under description are of extreme rarity.

PATNA AND BODOSAMAR AREA.—Throughout this area the principal hill formers are several varieties of garnetiferous gneiss. In the neighbourhood of Bolangir there are felspathic granites, which, over a limited area, are characterised by including lenticular masses of limestone, with which wollastonite is often much mixed. Close to the village of Darungarh, and also at Domaipali, there are graphite schists. The graphite, being merely a constituent of the schist, is of course not of very pure quality. Remarkably fine rock-crystals occur in some abundance near Bijkomar, to the south of Bolangir. They appear to occur in a nest in vein quartz, but no matrix was seen in contact with the nest as at present exposed.

KARIAL AREA.—In the northern part of this area the crystalline rocks consist chiefly of massive porphyritic granites, which are occasionally traversed by eurite veins.

Towards Kumuna a definite strike to about 20° east of north becomes apparent, and the porphyritic granites, which often include pink felspar and a green chloritic mineral, alternate with occasional beds of garnetiferous gneiss.

At Karial town and its neighbourhood the rocks do not continue to strike as above, but from east to west and east-south-east to west-north-west become the prevailing directions. To the east of Karial, at Tukla, and thence towards Ranipur Jural, a fine felspathic slightly garnetiferous granite occurs in bosses, some of which are of enormous size and perfectly symmetrical shape.

The Chaoria hill, to the south of Karial, rises to an elevation of over 3,000 feet, and from a long distance off its massive scarped outlines form a prominent feature in the landscape. This hill, and most of those in the group to which it belongs, is formed of garnetiferous gneiss.

KALAHANDI AREA.—The rocks of the Tel and Hathie valleys in Kalahandi are, probably, to a great extent, similar to those just described: but in the hilly portion of the eastern half

of Kalahandi quite a distinct group is met with. They consist principally of hornblendic rocks, being generally dioritic or syenitic; but there are also some crystalline felsites, in which there is no trace of hornblend. The few short traverses I was able to make across the outer ranges of this hilly region were not sufficient to enable me to define the limits of this group of rocks; and owing in a great measure to what I believe to be the origin of the rocks, the sections examined are of a nature very difficult to describe. In some few places, as in the Bodra-jor, these hornblendic rocks appear interbedded with schists and garnetiferous gneiss; but far more commonly the relations are of a most complicated and disturbed nature —one, in short, which can only be explained by regarding a portion of the rocks as intrusive. From the fact that these rocks occur sometimes interbedded with, while at others they envelop and surround, masses of gneiss, *but more particularly from the fact that an obscure foliation structure is sometimes apparent both in the diorites and felsites,* I am inclined to believe that these rocks are the product of original intrusive volcanic rocks, which have been affected by the general metamorphic action of the formation, and are not of plutonic derivation, as might be supposed from their more ordinary lithological characters.

It is impossible to give all the details which I have recorded here. It will be sufficient at present to give the observations made on the longest traverse. The ascent to Moulpatna is effected by a ghât, about 1,235 feet high, in which there is a confused mass of tumbled rocks. What to call the principal form, it is not easy to say. It contains both quartz and felspar, and in places might be called a petrosilex, but it passes into a pegmatite, and is occasionally even syenitic. Towards the top of the ghât, dioritic rocks, with a spheroidal (cannon ball) structure, appear; and close to Moulpatna, gneisses also are seen striking across some of the valleys, and apparently running under peaks and ridges of the diorites. In the section of the Indravati there are coarsely crystalline diorites and syenites, with no distinct sign of either bedding or foliation. Thence, eastward to the Baplaimali plateau, the rocks seen consist, for the most part, of the same rocks, boulders from which strew the surface in every direction. Gneissose rocks, however, occur also, and the plateau is formed of white ashy-looking beds, spotted with magnetic iron. They dip to east-south-east at angles of from 60° to 80°, and are capped by a thickness of 300 feet of laterite. I have once before, in Manbhum, met somewhat similar rocks. In that instance the dioritic rocks, being well exposed, in plan, in a flat country, often appeared to be interbedded with the ordinary metamorphic beds; but frequently they would suddenly leave the steady strike and pass across from between one pair of beds to another, and occasionally also occurred as considerable amorphous masses.

Jaipur Area.—The crystalline rocks of this area belong to three different groups. On the the north-east there appears to be a continuation of the just-described Kalahandi rocks. In the central northern portions there are ordinary metamorphic rocks, which are characterised by including an unusual proportion of hornblendic gneisses. These are well seen in the Boriguma, Poragarh, and Raigarh groups of hills. On the north-west of Jaipur the rocks seem to belong to the group of granites and porphyries of Nowagarh, about to be described. Throughout the whole of the area the rocks are much concealed by laterite and alluvium, and it would be useless to enumerate details here.

Bustar Area.—It is almost certain that crystalline rocks occur in the southern parts of Bustar, and it is not improbable that they will also be found in the north; but as there are none in the portion of Bustar examined by me, we may pass on to the next area.

Nowagarh Area.—Throughout Nowagarh I did not meet with a single completely satisfactory instance of a distinctly foliated or bedded metamorphic rock. Massive granites, syenites, and dioritic rocks have, with rare exceptions, alone been observed. It is a matter of some uncertainty whether these should be regarded as being of metamorphic or true igneous origin.

At the south-west corner of the district I traversed a section of these rocks between Risgaon and Amar, but failed to make out any regular sequence. Ordinary and porphyritic granites, together with some dioritic rocks, alternate, and it is just possible strike north and south with the hill ridges; but there is no distinct foliation or bedding. At Sobha there is a strong north and south ridge, formed of massive granitic porphyry, which is flanked by a dioritic rock on the east. Rocks of this character continue to Borgaon and Puljir, often forming bosses.

The nature of the granite-quartzite boundary has already been described on a previous page.

An extensive group of hills to the south of Nowagarh town consist chiefly also of ordinary and porphyritic granites, which are quite massive and without a trace of foliation. In the Pairi River, between Badomar and the quartzite boundary, there is a long section, in which the principal rock is a massive porphyritic granite, with pink felspar. Towards the north-west corner of the plateau the character of the boundary changes, as already mentioned, the granites running up to an elevation occasionally of as much as 900 feet, *e.g.*, in the Maliva hill, before they are capped by quartzites.

The Lohari hill to the west of Maliva is formed of granites in some variety, many of them being remarkably handsome rocks. One form, which contains both pink and white felspars, includes also epidote and a chloritic mineral; another, which is altogether white, becomes locally pegmatitic, owing to the absence of mica.

Towards Paragaon, further west, these rocks form groups of grotesque-looking bosses and tors. Beyond these again granites are traceable for some miles down the valley of the Pairi, where they occur at the bases of the small plateaus of quartzite and in the lateral valleys. Half way between Bourka and Kukda they are covered up and concealed by these younger rocks, and do not appear again in the country to the west for many miles.

AREA WEST OF THE RAIPUR BASIN.—West of a ridge of pseudomorphic quartz, which crosses the Raipur and Nagpur road at Waraband, there is a zone of crystalline rocks, which extends up to a point two or three miles west of Gortalou, where the above-mentioned Sakoli beds come in. The principal rocks of this zone are massive granites, which form, more especially near Chicholi, numerous bosses and tors. These granites are traversed by a series of more or less parallel runs of pseudomorphic quartz, two of which, and not improbably all, partake of the nature of lodes. The galena lode in the one, four miles to the west of Chicholi, has already been described by Mr. Blanford. This is, I believe, the only locality in India where fluor spar is known to occur. At the time of my visit I could see no traces of galena, the exposed portions having been, I was told, removed by stone-breakers, who were making road metal; but both in that lode and one north of the bungalow at Waraband I found traces of the copper carbonates.

Towards Bandara, and thence to Nagpur, metamorphic rocks, gneisses, and schists are again seen at intervals; but the rocks in the vicinity of the road are, for the most part, concealed by alluvium.

APPENDIX.

List of papers by the Geological Survey having reference to the geology of this area.

COAL-FIELDS.

Talchir (Blanford and Theobald): Memoirs, Vol. I, p. 34.
Cuttack, coal and iron of (Oldham): „ „ p. 1.
Orissa coal-fields (Ball): Report to Government, 1876.

Raigarh and Hingir, 1st notice (Ball):	Records,	Vol.	IV, p. 101.
„ „ 2nd „	„	„	VIII, p. 102.
Korba (Blanford)	„	„	III, p. 54.
Coal east of Chhattisgarh „	„	„	III, p. 71.
Atgarh sandstones (Ball)	„	„	X, p. 63.

MISCELLANEOUS.

Geological features of Bancoorah, Midnapore, and Orissa: Memoirs, Vol. I, p. 219.
Sketch of the geology of Orissa (Blanford): Records, Vol. V, p. 56.
Laterite of Orissa (Blanford): Memoirs, Vol. I, p. 280.
Lead vein at Chicholi, Raipur District (Blanford): Records, Vol. III, p. 44.
„ „ „ „ Vol. I, p. 37.

ON THE DIAMONDS, GOLD AND LEAD ORES, OF THE SAMBALPUR DISTRICT, BY V. BALL, M.A., F.G.S., *Geological Survey of India.*

DIAMONDS.

First discoverers unknown.

When, or by whom, diamonds were first discovered in Sambalpur is quite unknown. As in similar cases in many other parts of the old world, an impenetrable haze shrouds the ancient discoverers from our view.

Such evidence as exists tends to the belief, that the search for diamonds was carried on, under a rude system, for many centuries before the year 1850, when the British took possession of the district from the late Rajah, Narain Singh.

Mr. Motte's visit to Sambalpur.

So far as I have been able to ascertain, the first published notice of the subject is to be found in the narrative of a journey to Sambalpur, which was undertaken by Mr. Motte in the year 1766.* The object of this journey was to initiate a regular trade in diamonds with Sambalpur, Lord Clive being desirous of employing them as a convenient means for remitting money to England.

His attention had been drawn to Sambalpur by the fact that the Rajah had a few months previously sent a messenger with a rough diamond, weighing $16\frac{1}{2}$ carats, as a sample, together with an invitation to the Governor to depute a trustworthy person to purchase diamonds regularly.

The Governor proposed to Mr. Motte to make the speculation a joint concern, in which writes the latter: "I was to hold a third; he the other two: all the expenses to be borne by the concern. The proposal dazzled me, and I caught at it, without reflecting on the difficulties of the march, or on the barbarity of the country, &c."

In spite of his life being several times in danger from attacks by the natives, the loss of some of his followers by fever, and a varied chapter of other disasters, Mr. Motte was enabled to collect a considerable amount of interesting information about the country. Owing to the disturbed state of Sambalpur town, however, he was only able to purchase a few diamonds. After much prolonged negotiation, he was permitted to visit the junction of the Rivers Hebe (Ebe) and Mahanadi, where the diamonds were said to be found. A servant of the Rajah's who was in charge there informed him that "it was his business to search in the River Hebe, after the rains, for red earth, washed down from the mountains, in which earth diamonds were always found. I asked him if it would not be better to go to the mountains and dig for that earth. He answered, that it had been done, until the Mahrattas exacted a tribute from the country; and to do so now would only increase that tribute. He showed me several

* Asiatic Annual Register, London, 1799.

heaps of the red earth—some pieces, of the size of small pebbles, and so on, till it resembles coarse brick-dust—which had been washed, and the diamonds taken out." *

Lieutenant Kittoe, 1838.

The next mention of Sambalpur diamonds is to be found in Lieutenant Kittoe's account † of his journey, in the year 1838, through the forests of Orissa. He speaks of the people as being too apathetic and indolent to search for diamonds. His remarks on the localities where they occur seem to be derived from Mr. Motte's account, to which, indeed, he refers.

Major Ouseley, 1840.

Although published in the same number of the Asiatic Society's Journal,‡ we find a paper dated two years later, or in 1840, which was written by Major Ouseley, on the "*Process of washing for gold-dust and diamonds at Heera Khoond.*" In this we meet the following statement: "The Heera Khoond is that part of the river which runs south of the islands. The diamonds and gold-dust are said to be washed down the Ebe River, about four miles above the Heera Khoond; but as both are procurable as far as Sonpur, I am inclined to think there may be veins of gold along the Mahanadi."

No mention is made by Major Ouseley of the system of throwing a *bund* across one of the channels, as is described on a following page; but from my enquiries, I gathered that that method of washing was in practice for many years before the period of Major Ouseley's visit. He describes the operations of individual washers—not the combined efforts of the large number, which made that washing successful.

The diamonds found became the property of the Rajah, while the gold was the perquisite of the washers, who sold it for from twelve to fifteen rupees per tola.

Central Provinces Gazetteer.

In the *Central Provinces Gazetteer* it is stated that "during the period of native rule some fifteen or twenty villages were granted rent-free to a class called *Jhiras*, in consideration of their undertaking the search for diamonds. When the country lapsed in 1850, these villages were resumed." So far as can be gathered from the various sources of information, large and valuable diamonds have been occasionally met with; but the evidence on this point is somewhat conflicting. I do not think, however, that what we know is altogether consistent with the statement in the Gazetteer, that "the best stones ever found here were thin and flat, with flaws in them."

Largest diamonds found.

Local tradition speaks of one large diamond, which was found during the Mahratta occupation. Its size made its discovery too notorious; otherwise it would in all probability, like many other smaller ones, found at that time, never have reached the hands of the Mahratta Agent. It is said to have weighed two tolas and two mashas (at ten mashas to the tola),§ which would be about 316·2 grains troy, or expressed in carats 99·3. It would be impossible, of course, to make any estimate of the value of a rough stone of this size, regarding the purity, colour, &c., of which nothing is known.

Another diamond, in the possession of Narain Singh, is said to have weighed about a tola the equivalent of which, calculated as above, would be 45·35 carats. Already one of 16·5 carats has been mentioned as having been sent to Calcutta in 1766. One large but slightly flawed diamond, which I saw in the possession of a native in Sambalpur, was valued in Calcutta, after cutting, at Rs. 2,500. Mr. Emanuel, in his work on Diamonds and Precious

* This description suggests laterite as the matrix from which the diamonds were proximately derived. In this connection it may be noted that one of the principal sources of Cape diamonds is said to be a superficial ferruginous conglomerate.

† J. A. S. B., VIII, 1839, p. 375.

‡ *Ibid.* p. 1057.

§ (One masha = 14·37 grains troy): properly speaking there are 12 mashas in a standard tola.

Stones, gives some particulars regarding the diamonds of Sambulpur, but the limited information at his disposal does not appear to have been very accurate. He records one diamond of 84 grains having been found within the period of British rule, but does not mention his authority. There are said to be a good many diamonds still in the hands of the wealthier natives in Sambalpur. Of course, large diamonds such as those above mentioned were of exceptional occurrence; those ordinarily found are said to have weighed, however, two to four rutties, equal on an average, say, to the thirtieth part of a tola, or 4·7 grains = 1·48 carats. In the Geological Museum, there is at present a diamond which was sent to the Asiatic Society from Sambalpur by Major Ouseley. It weighs only ·855 grs. = ·26 carats.

As is usual, I believe, in all parts of India, the diamonds were classed as follows:—

Classification of diamonds.

I.—*Brahman.*—White, pure water.
II.—*Kshatrya.*—Rose or reddish.
III.—*Vasiya.*—Smoky.
IV.—*Sudra.*—Dark and impure.

Method of washing.

From personal enquiry from the oldest of the Jharas, or washers, at the village of Jhunan, and from various other sources, I have gathered the following details as to the manner in which the operations were carried on in the Rajah's time:—

In the centre of the Mahanadi, near Jhunan, there is an island, called Hira Khund,* which is about four miles long, and for that distance separates the waters of the river into two channels, as indicated on the accompanying map.

In each year, about the beginning of March or even later, when other work was slack and the level of the water was approaching its lowest, a large number of people,—according to some of my informants, as many as five thousand,—assembled, and as the result of a considerable amount of labor threw a *bund* across the mouth of the northern channel, its share of water being thus deflected into the southern. In the stagnant pools left in the former, sufficient water remained to enable the washers to wash the gravel accumulated between the rocks in their rude wooden trays and cradles.

Upon women seems to have fallen the chief burden of the actual washing, while the men collected the stuff. The implements employed and the method of washing were similar to those commonly adopted in gold-washing, save only that the finer gravel was not thrown away until it had been thoroughly searched for diamonds. Whatever gold was found became the property of the washer, as already stated. Those who were so fortunate as to find a valuable stone were rewarded by being given a village. According to some accounts, the washers, generally, held their villages and lands rent-free; but I think it most unlikely that all who were engaged in the operations should have done so.

So far as I could gather, the people did not regard their, in a manner, enforced services as involving any great hardship; they gave me to understand that they would be glad to see the annual search re-established on the old terms. Indeed, it is barely possible to conceive of the condition of the Jharas having been at any time worse than it is at present. No doubt the gambling element, which may be said to have been ever present in work of the above nature, commended it to the native mind.

According to Mr. Emanuel, these people show traces of Negro blood, and hence it has been concluded that they are the "descendants of slaves imported by one of the Conquerors of India." They are, however, I should say, an aboriginal tribe, showing neither in their complexions, character of their features, nor hair, the slightest trace of a Negro origin.

* Lit., Diamond mine.

Indian Government become proprietors.

When Sambalpur was taken over in 1850, the Government offered to lease out the right to seek for diamonds. And in 1856 a notification appeared in the Gazette describing the prospect in somewhat glowing terms.* For a short time the lease was held by a European at the very low rate of two hundred rupees per annum; but as it was given up voluntarily, it may be concluded that the farmer did not make it pay. The facts that the Government resumed possession of the rent-free villages, and that the Rajah's operations were carried on without any original outlay, materially altered the case, and rendered the employment of a considerable amount of capital, then as it would be now, an absolute necessity.

No diamonds found recently.

Within the past few years, statements have gone the round of the Indian papers to the effect that diamonds are occasionally found now by the gold-washers of Sambalpur. All my enquiries failed to elicit a single authentic case, and the gold-washers I spoke to and saw at work assured me that the statements were incorrect. Moreover, they did not appear to expect to find any, as I did not observe that they even examined the gravel when washing.

Source of the diamonds.

With regard to the origin of the diamonds, the geological structure of the country leaves but little room for doubt as to the source from whence they are derived. Coincident with their occurrence is that of a group of rocks which has been shown to be referable to the Vindhyan series, certain members of which series are found in the vicinity of all the known diamond-yielding localities in India,† and, in the cases of actual rock-workings, are found to constitute the original matrix of the gems.

In several of the previous accounts, the belief is either stated or implied that the diamonds are brought into the Mahanadi by its large tributary the Ebe. It would not, of course, help the point I am endeavouring to establish to say that the Ebe, at least within our area, except indirectly,‡ is not fed by waters which pass over Vindhyan rocks, but I have the positive assurance of the natives that diamonds have not been found in that river, although gold is and has been regularly washed for. On the other hand, diamonds have been found in the bed of the Mahanadi as far west as Chanderpur and at other intermediate places, well within the area which is exclusively occupied by the quartzites, shales, and limestones of Vindhyan age.

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* NOTIFICATION.—Persons desirous of working the valuable diamond mines of the Mahanadi are hereby informed, that after the 1st of January 1857, the privilege will be leased to any one who shall be considered to have made the most eligible offer for the same.

2nd.—Besides precious stones, gold is to be met with in considerable quantities, and the party who may rent the privilege of working the diamond mines will be entitled to appropriate all diamonds, precious stones, and gold that he may find in the bed of that river within the limits of the Sambalpur Division during the period of his lease.

3rd.—Unless a proportional inducement be offered, a lease will not be granted for a period of more than three years, but applicants are requested to state at what rate per annum they are agreeable to rent the mines, and how many years' lease they are desirous of obtaining, with particulars of all modifications they may wish made in the conditions now set forth.

4th.—Parties proposing to rent the mines must be prepared to lodge in the treasury at Sambalpur one year's rent in advance as security for the fulfilment of the terms of the lease taken up by them, and the rent will be demanded in three instalments yearly. If at any time during the lease, the period of one year, calculated from the date of payment of the last instalment, be allowed to elapse without the payment of an instalment, the security money shall be forfeited and the lease considered to have expired.

† *Conf.* Medlicott, Bundelkund, Mem. G. S. I., Vol. II, p. 65.
„ Mallet, Vindhyan Series, *id.*, Vol. VII, p. 69.
„ King, Kadapah and Karnul formations, *id.*, Vol. VIII, p. 87.

‡ By a few small streams which rise in an isolated outlying hill called Gotwaki. It should be stated, however, that one of the tributaries of the Ebe, the Icha, far away in Gangpur, is said to produce diamonds; but the statement needs confirmation, and the geology of that part of the country is at present quite unknown. Near its sources, far away in Chota Nagpur, I have heard the Ebe spoken of as the Hira Nad.

Hira Khund.

The mere fact that the place Hira Khund, where the diamonds were washed, is on metamorphic rocks, may be readily explained by the physical features of the ground. The rocky nature of the bed there and the double channel caused by the island afforded unusual facilities for, in the first place, the retention of the diamonds brought down by the river; and secondly, for the operations by which the bed could on one side be laid bare and the gravel washed by the simple contrivances known to the natives.

Rocks similar to diamond matrix at Panna and Banaganpilli.

Most favorable localities for future operations.

It is impossible to say at present which the actual bed or beds may be from whence the diamonds have been derived, as there is no record or appearance of the rock ever having been worked; but from the general lithological resemblance of the sandstones and shales of the Barapahar hills and the outlier at Borla with the diamond-bearing beds and their associates at Panna in Bundilkhana and Banaganpilli in Karnul, I have very little hesitation in pointing to these rocks as in all probability including the matrix. Above Padampur the Mahanadi runs through rocks of this age, and I should therefore strongly urge upon any one who may hereafter embark upon the undertaking of searching for diamonds in Sambalpur to confine his operations, in the first instance, to the streams and small rivers which rise in the Barapahar hills and join the Mahanadi on the south. Besides the obvious advantage of being, as I believe would be found to be the case, close to the matrix, these streams would, I think, be found to contain facilities for obtaining a sufficient head of water for washing purposes. The works would require but a few laborers, and could be carried on for a much longer period every year, say for eight or nine months, than would be possible in the case of the washings in the bed of the Mahanadi itself.

According to the accounts received by me, the southern channel of the Mahanadi used not to be emptied in the Rajah's time; but from various causes I should expect it to yield, proportionally, a larger number of diamonds than the northern. In the first place, the stronger current in it would be more efficient in removing the substances of less specific gravity than diamonds, while the rocks and deep holes in it afford admirable means for the retention of the latter. Again, it is in direct contact with the sandstones and shales (presumedly diamond-bearing) of the outlying ridge at Borla. Owing to the greater body of water to be dealt with, it would be found to be more difficult to divert than that which flows in the northern channel; but the result in a greater harvest of diamonds would probably far more than compensate for the greater expenditure incurred.

Similar rocks further south not known to be diamond-bearing.

In the country to the south of Sambalpur, in Karial and Nowagarh, where rocks of similar age occur to those of the Barapahar hills, I failed to find any traditional record of diamonds having ever been found or searched for. It is just possible, however, that the names of several villages in which the word *Hira* (diamond) occurs may have reference to some long-forgotten discovery.

Pebbles.

In addition to diamonds, pebbles of Beryl, Topaz, Carbuncle, Amethyst, Cornelian, and clear quartz used to be collected in the Mahanadi; but I have not seen either sapphires or rubies. It is probable that the matrix of these, or most of them, exists in the metamorphic rocks, and is therefore distinct from that of the diamonds.

GOLD.

In all probability gold occurs pretty generally throughout those portions of the district in which metamorphic rocks prevail. So far as I have been able to gather from personal observation, the washers confine themselves to the beds of the Mahanadi and Ebe; but in the rains they are said to leave the larger rivers and wash in the small jungle-streams.

In the Ebe, below Tahood, I saw a party of gold-washers encamped on the sand. The places where they were actually washing were within the area occupied by rocks of Talchir age; but whether the gold was proximately derived from the Talchirs or had been brought down by the river, as is possible, from the metamorphic rocks, a short distance higher up, I am unable to say.

Gold washed for within Talchir boundary.

There is of course no *primâ facie* improbability in the Talchir rocks containing gold. On the contrary, the boulder bed, including, as it does, such a large proportion of materials directly derived from the metamorphic rocks, might naturally be expected to contain gold. In the original description of the Talchir coal-field the following passage occurs:—"Gold is occasionally washed in the Tikaria River, and was also a few years since obtained from the sands of the Ouli." The latter case is rather interesting, since the localities are in a sandstone country, through which the Ouli mainly flows.* In this connection it may be mentioned that in Australia, quite recently, a conglomerate bed of carboniferous age has been found to be auriferous.†

As to the methods employed by, and the earnings of, the gold-washers, the remarks made in a paper by me on the gold of Singbhum‡ apply equally to Sambalpur, and need not be repeated here.

Method of washing, &c.

LEAD ORES.

Galena at Jhunan.—On the occasion of my first visit to Sambalpur in 1874, Captain Bowie, at that time Deputy Commissioner of the district, shewed me some specimens of galena which had remained in the possession of the Tehsildar and other residents since before the occupation of the district in 1850. The history of this galena appeared to be as follows:—

It was discovered in the bed of the Mahanadi at Jhunan, 10 miles west of Sambalpur, in the Rajah's time, and was at first extracted to a small extent by the people and used as a substitute for *Surma* or antimony for anointing the eyes. Suddenly, however, the Rajah, Narain Singh, becoming afraid that the discovery might attract the notice of Europeans, ordered the excavation to be stopped and the lode to be covered up and concealed.

First discovery.

During the 25 years or so which had elapsed since that time, the river has somewhat shifted its channel, and sand and clay had been deposited against the bank where, according to the villager's recollection, the lode was originally exposed. By Captain Bowie's orders, a party of these villagers were set to re-discover the position, and on the 27th December we visited the spot and found that several trenches had been dug in the sand; these, owing to the influx of water and a shifting layer of quicksand, had failed to lay bare the face of rock, but from the fragments of stone brought up it was apparent that the lode had not been struck. The rocks seen in the bed of the river consist chiefly of a coarse granular-looking granitic gneiss, which strikes from about north-west to south-east. Observing some small veins of quartz to run with the strike, it seemed probable that the lode would do so too, and I accordingly laid out a line for a new trench, which resulted a few days later in the re-discovery of the deposit.

Re-discovery.

Among the first specimens of galena brought into Sambalpur was one weighing 1 maund 6 seers 4 chittacks, of which about one-half consisted of galena, the remainder being made up of portions of the quartz gangue and sides of the lode.§ In some of these

* Mem., G. S. I., Vol. I, p. 88.
† *Vide* Geol. Mag., 1877, p. 286.
‡ Records, Vol. II, p. 11.
§ This fine sample is now in the Geological Museum.

first specimens, the presence of antimony was apparent, and there were also traces of the carbonates of copper. On re-visiting the locality, I was able to satisfy myself that the deposit occurred as a true lode which, though striking, apparently with the surrounding granitic gneiss rocks, has a different underlie, and cuts across the plains of their bedding and foliation. At this stage, what I subsequently found to be the case was not apparent, *viz.*, that the lode does not rise to the surface or outcrop of the gneiss above the bed of the river, but that it commences somewhat abruptly several feet below. In the portion of the lode exposed, which was about six feet in length, the distance between the walls varied from 16 to 19 inches. The strike was from 35° north-of-west to 35° south-of-east with an underlie of 45°, to 35° east-of-north, that of the surrounding rocks being in places 60°.

Deposit a true lode.

The gangue consists of quartz, which is permeated in every direction by nests and strings of galena. In places massive ore stretches from wall to wall. Besides hydrated peroxide of iron which forms a kind of *gossan* with the quartz, I found no trace of any foreign minerals in the gangue.

Nature of gangue.

On assay, the galena yielded 12 oz. 5 dwts. of silver to the ton of lead. This, though a small percentage, would be sufficient under favorable circumstances to yield a profit on the cost of extraction.

Silver.

On the whole, the aspect of the lode, as seen at that time in the bank of the river, was so promising that, at Captain Bowie's request, I laid out a system of trenches by which its extension inland from the river might be proved. Subsequently, a small grant of money was made by the Central Provinces Government for the purpose of making some experimental excavation, and operations were forthwith commenced. Just before leaving Sambalpur in April 1875, I again visited the locality to see what progress had been made. I found that a trench about 20 feet deep had been dug through the alluvium some 60 yards from the bank of the river; but it had not been carried to a sufficient depth to lay bare the rock throughout. On this occasion I first found out what I have above noticed, namely, that the lode does not, on the scarped river face, rise to the outcrop of the rock. This, of course, renders the chance of striking it by mere superficial trenches in the rock very much smaller than it would otherwise be.

Preliminary exploration.

In the absence of any one who could take charge of the work on the spot, I did not recommend any operations in the river bed itself, as, if injudiciously carried out, they would not improbably injure the prospects of successful mining hereafter by destroying all trace of the lode and leaving in its place an excavation open to the floods. Such work as had been done was, from the want of skilled guidance, not of a conclusive character. I therefore could not recommend any further outlay being incurred on the exploration, and accordingly nothing more has been done in the matter since 1875.

Galena at Padampur.—The above is not the only locality in Sambalpur where galena has been found. Twenty-four miles farther up the Mahanadi, in the bed of the river under the village of Padampur, strings and small nests of galena occur somewhat irregularly in a bed of Vindhyan limestone. This deposit does not appear to exist in sufficient abundance to become of any economic importance.

To the north of Sambalpur, near Talpuchia on the Ebe, some rolled pebbles, consisting of a mixture of the oxide and carbonate of lead, have been found. Whence they were originally derived is uncertain, but I think it possible that the matrix may exist in a small hill to the north of Talpuchia, which consists of fault-rock and *gossan*.

Carbonate of lead.

NOTE ON "ERYON COMP. BARROVENSIS," MCCOY, FROM THE SRIPERMATUR GROUP NEAR MADRAS, BY OTTOKAR FEISTMANTEL, M.D.

Amongst the fossils from the Sripermatur group, near Madras, which were sent in by Mr. Foote, and which contain numerous plant impressions and remains of marine animals, there is also the impression of a fossil Crustacean. The impression shows a portion of the carapace, a fragment of one leg, and the abdomen. The specimen is very flatly pressed, although the adnexa of the epidermis are pretty well marked. From the extremely flat carapace, and from the condition of the seventh segment and of the caudal plates, is shown that our specimen belongs to the genus *Eryon*, Desm.

CRUSTACEA, DECAPODA, MACRURA.

ERYONES, Desm.

Eryon comp. Barrovensis, McCoy, Figs. 1, 2, 3.

1849. McCoy: On the classification of some British fossil Crustacea. Ann. and Mag. Nat. H., vol. iv., 2nd series, p. 172.
1858. William Jardine: Memoirs of Hugh Edwin Strickland, London, p. 227 (figure).
1862. Oppel: Palæontologische Mittheilungen I. Uber jurrassische Crustacean, p. 11.
1866. Woodward (H.): Notes on the species of the genus Eryon, &c. Qu. Journ. Geol. Soc. of London, vol. xxii, p. 495, &c., pl. xxv, fig. 1.

In our specimen there is only about one-third of the carapace preserved, very flatly pressed. The lateral margin, as far as can be seen from the preserved portion, was denticulated; the posterior margin is slightly emarginated: at the point of junction of the lateral and posterior margins there seems to have been a somewhat projecting angle. In the median line of the carapace are seen two oblong impressions, which seem to be connected, and of which the lower one, near the posterior margin, is deeper and narrower.

These two impressions answer, of course, to tubercles of the same form on the surface of the real specimen (ours being only a negative impression).

About in the middle between this median series of tubercle impressions and the lateral margin, there is seen another longitudinal slight impression, running in an oblique direction from the posterior margin towards the anterior portion and the median line. This impression must have been caused by a prominent ridge, which had the same direction.

The breadth of the carapace at the broadest part was 44 mm.: of its length I cannot judge. There is a fragment of a leg; and from its size and form, I must judge that it belongs to one of the first pair of legs.

The abdomen is about one-third narrower than the carapace, as far as can be seen from the impression.

Seven segments are well seen. The first is narrower and much shorter than the others: in the median line there is an oblong, deep impression: the lateral portions of this segment are not well shown.

The following four segments are almost equally long, but they get a little narrower towards the seventh segment. Each of these segments shows in the median line an oblong, pretty deep impression and, besides this, two lateral tubercular impressions, quite close to the anterior margin. The sixth segment shows the same condition as the four preceding ones; but is narrower. It continues into the seventh, which is much narrower, but longer, of a triangular form, ending in a pretty sharp point. At its base this segment is a little constricted, but gains again its entire breadth, finishing from thence in the pointed apex.

The lateral margins of this seventh segment are finely and sharply denticulated.

On both sides of the median line of this seventh segment are seen two oblong spaces, beginning broader at the base of the segment, and becoming very attenuated towards the apex; their extension is very well characterised and defined by closely set, sharply marked, minute holes, like pricks of a needle. I suppose these two spaces are the impressions of two similar ridges, which in the living animal were in this place on the upper surface.

On both sides of this seventh segment are the caudal plates, two of them on each side, and they form, together with the median seventh segment, a pentaphyllous caudal fin. These caudal plates are connected by a special intervening segmental portion with the sixth segment. Their form is broadly, sub-quadrately oval; and they are, as far as I can observe, traversed by a longitudinal ridge—in our specimen, of course, very flattened.

On one of the outer plates (in the drawing the right one) I can observe, nearer the apical margin (the extremity), a curved line, which, I suppose, represents a suture in this plate. This would agree with Mr. H. Woodward's observation on *Eryon Barrovensis* (1866, *l. c.*, p. 496), while Dr. Oppel (1862, *l. c.*, p. 9) stated that the caudal plates are undivided, as is, in fact, the case with the forms from the "Solenhofen-Schiefer." Mr. H. Woodward marked this suture in the caudal plates as an *important* distinction of *Eryon Barrovensis*, from the Solenhofen species; and the character must be used to the same extent in our specimen. On the inner caudal plates, I could observe that their margin is finely denticulated. The whole surface of the abdomen, as preserved in our specimen, shows very fine minute holes, which extend also into the tubercular impressions in the median line of the segments. These little holes are only the impressions of little warts which covered the epidermis of the living animal.

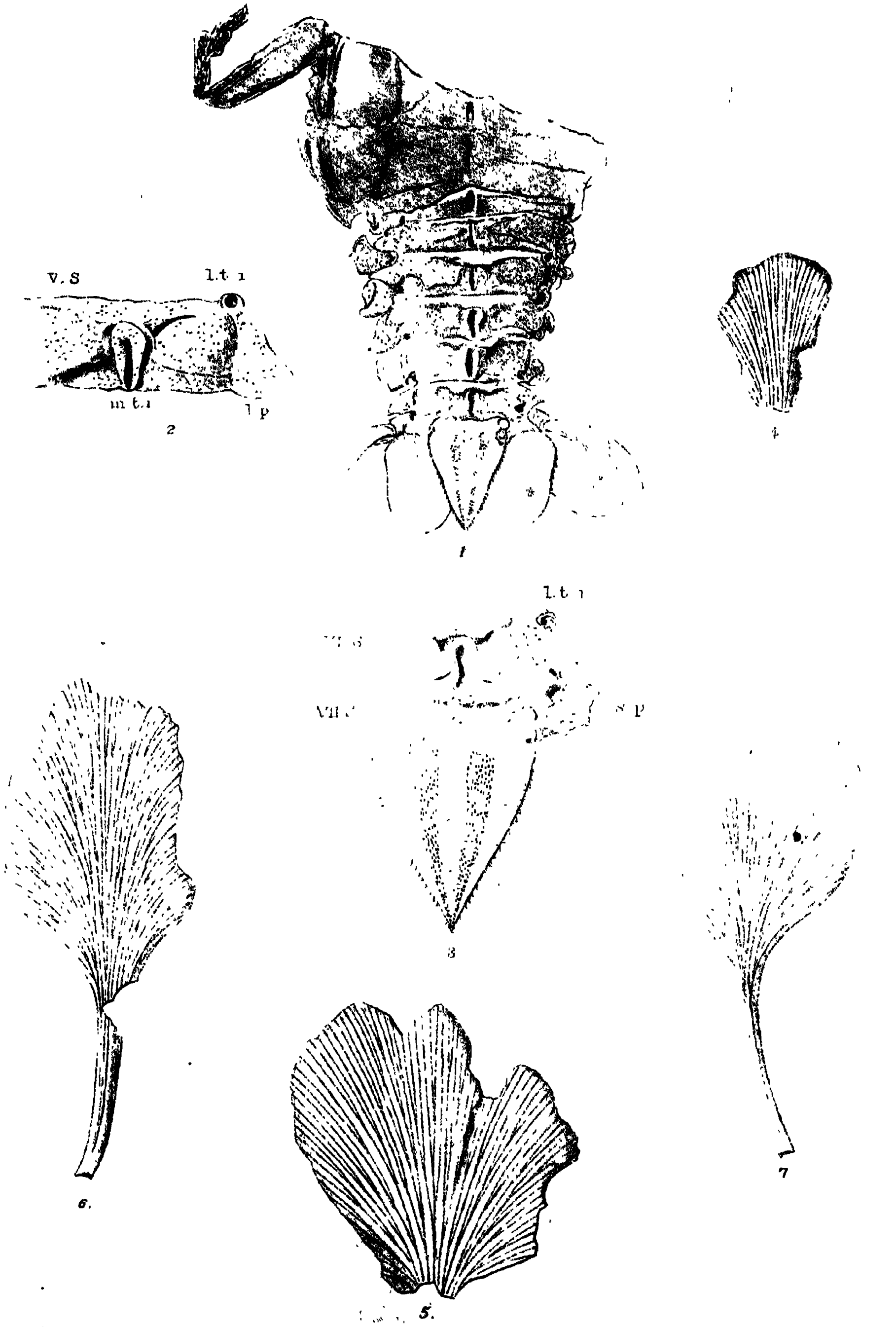
The lateral processes (epimera) of the segments are a little decreasing in size towards the last segment, and are rounded in their anterior marginal portion. The process of the last segment is more acuminate; and to this are joined the segmental portions, on which the caudal plates are inserted. These lateral processes show also the minute holes, which I mentioned before to be found on the whole surface.

Dimensions of the abdomen.

	Mm.
a. From the posterior margin of the carapace to the apex of the 7th segment	48·0
b. Length of 1st segment	3·5
c. of 2nd „	·5
d. of 3rd	·6
e. „ of 4th	·6
f. „ of 5th	·6
g. „ of 6th	5·5
h. „ of 7th „	16·0
Breadth of the same at base	11·0
i. Breadth of inner caudal plates	8·5
Length of the same	14·0
k. Length of outer caudal plate from point of insertion to the apex	16·5
l. Greatest breadth of the same	11·0
m. Distance of suture in the caudal plate from point of insertion	11·5
n. Breadth of 1st segment	28·5

COMPARISON.—The very flat and broad carapace, the structure of the seven segments with median and lateral tubercles on the anterior margin, the form and structure of the caudal plates, leave no doubt that our specimen is an *Eryon*. The two most closely related forms are *Eryon Hartmanni*, v. M., and *Eryon Barrovensis*, McCoy. The general resemblance is very close.

ERYON HARTMANNI is figured by H. v. Meyer in N. Act. Ac. Leop. Carol., vol. xviii. pt. i, pl. xi-xii. This species is, however, much larger in all dimensions, although the general form of the carapace would agree. The segments are much broader and longer; the



Lith^d by J Schaumburg.

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median tubercles are smaller in proportion to the segments, than is the case in our specimen; the lateral tubercles are hardly marked, while they are distinct in our specimen. The lateral processes in *Eryon Hartmanni* are more decreasing in size towards the posterior segments than in our specimen. The seventh segment is broader in *Eryon Hartmanni,* the lateral margins being more curved. The formation of the inner pair of the caudal plates in our specimen, however, agrees with the same in *Eryon Hartmanni;* the outer caudal plates are not well exhibited in H. v. Meyer's drawings. The surface of the abdomen shows also well the warts of the epidermis.

Our specimen shows, however, a closer resemblance with *Eryon Barrovensis,* McCoy, when compared with H. Woodward's restored figure (*l. c.*): it shows the median series of tubercles in the carapace, and also the lateral oblique ridges; the median and lateral tubercles of the segments; also the lateral processes are identical with those in *Eryon Barrovensis,* McCoy. The seventh segment agrees in general form also well with Mr. Woodward's drawing, although this figure does not show the two longitudinal spaces, set with the minute holes; but in the figure given in W. Jardine's work (*l. c.*), p. 227, the seventh segment shows precisely the same two dotted spaces as are seen in our specimen.

The caudal plates are of importance. One of the outer caudal plates in our specimen (the right in the figure) shows at the extremity, as already mentioned, a *suture,* which H. Woodward has shown also in his figure, and pointed out as an important distinction from the Solenhofen specimens; and the same suture is also shown distinctly in W. Jardine's figure (*l. c.*) This character I consider as most important in the comparison of our specimen with *Eryon Barrovensis,* McCoy. The inner pair of caudal plates is in our specimen broader on the point of insertion than is shown in Woodward's drawing; but in W. Jardine's figure they show almost the same condition.

With the *Eryones* from the Solenhofen-Schiefer, as they are figured in Graf Münster's Beiträge" and in Dr. Oppel's Palæontologische Mittheilungen, our specimen cannot be well compared, most of these having the caudal plates more triangular; but the want of a suture in the outer plates forms the chief distinction.

The genus *Eryma,* Meyer, which has a somewhat similar caudal fin, can, of course, not be taken into consideration, the carapace being different.

From what I have said, it would follow that we have here a form, which has its closest ally in Eryon Barrovensis, McCoy, *of the English Lias: in fact, our specimen differs from that described by Mr. Woodward only by its being a little smaller (the abdomen is 22 mm. shorter), while it agrees completely in size, &c., with that given in W. Jardine's work* (*l. c.*); *so that there is hardly any objection to consider our specimen as* Eryon Barrovensis, McCoy.

As I mentioned, our specimen is from the Sripermatur group (upper Gondwanas), west of Madras, which contains plants and animals, the plants being, to a great extent, of the type of the Rajmahal flora, which I determined to be of liassic age.

This Sripermatur group has its immediate representative in the Ragavapuram shales, on the lower Godávari; and these shales, as described by Mr. King, overlie beds of the age of the Rajmahal group.

Explanation of Figures 1—3.

Fig. 1—Represents the specimen of natural size, showing a portion of the carapace, one leg, segments, and caudal fin.

Fig. 2—Fifth segment twice enlarged, showing the median (m. t. i.) and lateral tubercular impression (l. t. i.), the dotted surface and lateral processes (l. pr.).

Fig. 3—Is the sixth and seventh segment together, twice enlarged, showing lateral tubercular impression (l. t. i.), segmental portion (s. p.), and the dotted spaces of the seventh segment.

NOTES ON FOSSIL FLORAS IN INDIA, BY OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

XVII.—Some elements of the Artic and Siberian Jurassic Flora amongst the plants of the Gondwana-system.

1. GINGKO. *Lin.* (*Heer*).

Prof. Heer, the illustrious describer of the Artic Fossil Flora, has, in his recent publications, disclosed to our knowledge the Jurassic Floras of Spitzbergen (Cape Boheman) and of Eastern Siberia and the Amur countries. A most interesting fact is, I think, the establishment of the genus *Gingko* (*Salisburia*) among the Jurassic plant remains—a genus which is at present living in Japan and China. Species of this genus are described from Siberia and Spitzbergen.

Some forms of this genus were at first described from the Yorkshire Oolite as *Cyclopteris*, Bgt., *Cyclopteris digitata* being best known. Later, the name *Bajera* was established for these forms by Fr. Braun. Prof. Heer was so fortunate as to receive more complete specimens, from which he proved them to belong to the genus *Gingko*. The fossil representatives of *Gingko* in the Jurassic formation at present known are—

(1) Spitzbergen—Cape Boheman.*

Gingko digitata, Heer, with varieties.
Gingko Huttoni, H.
Gingko integriuscula, H.

(2) England—Scarborough: †

Gingko digitata, H. (*Cyclopteris digitata*, Bgt.).
Gingko Huttoni, H. (*Cyclopteris Huttoni*, Stbg.).

(3) South-Eastern Russia—Kamenka, near Izoum: ‡

Cyclopteris incisa, Eichw.—Closely related with *Gingko Huttoni*, H.
Gingko digitata, H. (as *Cyclopteris*).

(4) East Siberia (Irkutsk) and Amur countries: §

Gingko Huttoni, H. (E. Sib.).
Gingko Schmidtiana, H. (E. Sib.).
Gingko flabellata, H. (E. Sib.; Amur c.).
Gingko pusilla, H. (E. Sib.; Amur c.).
Gingko Sibirica, H. (E. Sib.; Amur c.).
Gingko lepida, H. (E. Sib.).
Gingko concinna, (E. Sib.).

Forms of this genus were previously also described from Cretaceous and Miocene (Greenland, Senegaglia, N.-W. America, &c.).

* Heer, Flora fossilis arctica, Vol. IV.
† Brongniart, Hist. vegét. foss., tab. 61. f. 2. 3: Lindley and Hutton, Foss. Flora of Gr. Brit., tab. 64.
‡ Eichwald, Lethaea Rossica, Vol. II.
§ Heer, Flora fossilis arctica, Vol. IV.

I have to record two forms from our Indian Jurassic deposits (upper portion of Gondwana system)—

GINKO LOBATA, Feistm., figs. 4, 5.
Cyclopteris lobata, Rec. Geol. Surv., 1876, p. 126.
Gingko, Rec. Geol. Surv., 1877, p. 144.

This species is from the Jabalpur group (Sher River in the Satpura basin), and was described by me at first as *Cyclopteris*, before Heer had established the genus *Gingko.* I distinctly pointed out its relation to *Cyclopteris digitata*, Bgt., which itself is now a *Gingko digitata*, H., of which a splendid specimen is figured in the Jurassic Flora of Spitzbergen, pl. x, f. 2, by Prof. Heer.

I saw a difference in our specimen from *Gingko digitata* in its not being so deeply incised, and called it therefore *Cyclopteris lobata*, which name I keep in transferring the form to *Gingko*, but state again, that it is very closely related with *Gingko digitata* from the Yorkshire Oolite (Lower Oolite).

GINGKO CRASSIPES, *sp. n.*, figs. 6, 7.

Foliis oblonge, rotundatis, basim versus attenuatis, margine indivisis, hinc inde sublobatis, nervis creberrimis repetito dichotomis, e basi radiatim eggredientibus, pedicello crassiusculo, linea notato.

This species agrees in the condition of the leaf with *Gingko integriuscula*, H., from Spitzbergen; our leaf, however, is more oblong: the chief distinction is the thicker peduncle of our species, which shows well the point of insertion. The margin is undivided; here and there slightly lobed. Veins are numerous, repeatedly forked, radiary.

Locality.—Our specimens (four altogether) were found in the Ragavapuram shales on the Lower Godavari.

Gingko lobata, Feistm., is from the same place, and in fact preserved in the same specimen of the Jabalpur group on which I first saw the *Glossopteris* in these beds, and *Gingko crassipes*, sp. n., is from a group which is on the same horizon as the Sripermatur group, from which I described the *Eryon* comp. *Barrovensis* and as the Kota-Maleri beds.

Gingko Huttoni, H., from the Middle Jura in Spitzbergen and E. Siberia, is, according to Prof. Heer's opinion, very close to the living *Gingko biloba*, Linn., in Japan and China.

2. Two other types of fossil plants from the Jabalpur group, which I have not figured in the plates to be published with the descriptions of the fossil flora of that group, are represented in the annexed figs. 8 and 9, as I think they are of some interest.

Fig. 8 shows linear impressions, with oval or round swellings in their length. The drawing represents them rather too distinctly. The only fossil which this specimen recalls, is the recently-described genus *Czekanowskia*, Heer (*l. c.*), which is said to be a conifer, the lineal impressions representing leaves, and the swellings being caused by parasitic fungi. This specimen is from Jabalpur.

Fig. 9 represents a set of lanceolate leaves, apparently converging towards the lower part, as if they should join there. As far as can be seen, they are traversed by longitudinal single veins. This specimen is from the Sher River and recalls Prof. Heer's *Phönicopsis* (*l. c.*).

I do not at present intend to identify the figured specimens with the forms mentioned from E. Siberia and the Amur countries. I wish only to indicate the possible relations, as it

may happen that by the discovery of more and better specimens from the Jabalpur group, the identity with those forms will be proved. I point to these three forms specially, as in a general paper they might be overlooked; but the relations of our Indian Jurassic floras with those in Asia are much closer.

If we take the flora of the Jabalpur-Kach group, with the somewhat older flora of the Rajmahal group, then we find its representatives in South Russia (Izoum, near Kamenka), in Immeretia to the south, and Daghestan to the north of the Caucasus, in the Elburz mountains, near Astrabad, in Irkutsk (E. Siberia), in the Amur countries, in Japan, in China, west of Pekin, and in the Province Hoopeh; and, according to Baron von Richthofen's opinion, the coal-beds of Sze-Chwán, Yunnan, &c., are of about the same age. In my paper on the flora of the Jabalpur group I shall discuss these relations more in detail, showing the identities.

3. A NEW DICKSONIA L'HERIT FROM THE DAMUDA SERIES, Figs. 10—11.

In the continuation of the Rajmahal Flora* I have described a *Dicksonia* as *Dicks. Bindrabunensis;* but as at that time I was not aware of Prof. Heer's work on the Jurassic Flora of Eastern Siberia and the Amur countries having been published, I said, page 23, that "we do not find this name as a fossil genus." I am glad to see that, although Prof. Heer was prior in establishing the genus as fossil, I was also correct in my diagnosis, which I made independently.

I have now to record a form from the Damuda series, which is very close to one of Prof. Heer's species. The specimens in question are from the Raniganj and Jherria coal-fields: one of the specimens from the latter locality which were collected by Mr. Hughes, I have figured (fig. 10), and two leaflets are enlarged in figs. 10*a* and 10*b*.

The sub-opposite pinnæ rise from the rhachis, at subacute angles, turning upwards. The chief rhachis and the rhachis of the pinnulæ are traversed by a median line. The pinnulæ are membranaceous, closely set, oblong, attenuated towards the base, pretty acute at their apex, and decurrent on the rhachis.

The pinnulæ, which are closer to the chief rhachis (about 3 or 4) have a sinuately denticulated margin, while those more distant have almost an entire margin, and only here and there the averted margin shows a slight sinuation. The enlarged pinnulæ, figs. 10*a* and 10*b*, show this.

There is a chief vein coming out more from the lower part of the base, but almost at the same spot a secondary vein passes out from the chief vein; besides this, other secondary veins pass out at pretty acute angles and are forked. No fructification is preserved.

There is especially one species in Prof. Heer's work on the Flora of the Amur countries, *Dicksonia concinna* (*l. c.*), page 87, to which our form is closely allied; and Heer's fig. 2, on tab. xvi, approaches very much my drawing, so that I consider both as belonging to the same group.

In fig. 11 is a pinna of another specimen, which approaches still more Heer's drawings.

This is not the only form in our Damudas which is a Siberian element. Prof. Heer describes a *Phyllotheca Sibirica,* to which, as he himself remarks, the *Phyllotheca australis,* McCoy, is most closely allied; but also our *Phyllotheca indica,* Bunb., from the Raniganj group, is almost undistinguishable from the Jurassic form in Siberia.

* Palæontol. Indica, Ser. II, 2, pp. 23, 24.

Besides these, the Jurassic Flora of Siberia and the Amur countries is very rich in forms of the group of *Alethopteris Whitbyensis*, which also is represented in the Damudas, and is again frequent in the Upper Gondwanas.

Explanation of Figs. 4 *to* 11.

Figs. 4, 5.—Two leaves of *Gingko lobata.*

Figs. 6, 7.—Two leaves, with peduncles, of *Gingko crassipes.*

Fig. 8.—*Czekanowskia,* sp.

Several leaf fragments, which I believe to belong to this peculiar form.

Fig. 9.—*Phönicopsis,* sp.

A specimen, which I refer to this genus.

Figs 10, 11, (10*a*, 10*b*, 11*a*).—*Dicksonia* comp. *concinna,* Heer, pinnæ of natural size and pinnulæ enlarged.

XVIII.—NOTES ON VERTEBRARIA, SCHIZONEURA ZEUGOPHYLLITES, AND NÖGGERATHIA.

From the Indian Damuda series originally two species of *Vertebraria* were described, *i. e.*, *Vertebraria radiata*, Royle, and *Vertebraria indica*, Royle,* which, however, represent only one and the same form, the latter being the longitudinal section, the former the transversal section. Both were (1850) placed by Unger† with *Sphenophyllum.* But as this was only an incorrect supposition, we have to keep the original names.

From Australia similar relations are to be recorded. There is described a *Vertebraria australis*, McCoy,‡ which is the only figure of this genus with this name. It is a transversel section, and was compared with our *Vertebraria radiata*, Royle. This *Vertebraria australis*, McCoy, however, was also placed by Unger with *Sphenophyllum* as *Sphenophyllum australe.* As, however, this transferring of the *Vertebraria australis* to the genus *Sphenophyllum* was incorrect, the name *Vertebraria* is to be retained also for this form.

But there is in Dana's Geology (United States Exploring Expedition, 1849, pl. 14) another form, described as *Clasteria australis.* The closer examination, however, shows that *Clasteria australis*, Dana, is to *Vertebraria australis*, McCoy, in the same relation as is *Vertebraria indica*, Royle, to *Vertebraria radiata*, Royle, or, in other words, *Clasteria australis*, Dana, is the longitudinal section of *Vertebraria australis*, McCoy, both representing one species.

We have here therefore a fossil plant from Australia which within four years was described with three different names, *i. e.*, *Vertebraria australis*, McCoy (1847), *Clasteria australis*, Dana (1849), and *Sphenophyllum australe*, Unger (1850); and for which the name *Vertebraria australis*, McCoy, as the original one, has to be kept.

I thought it useful to point to these relations, in order to prevent mistakes, and to show how in some papers on the Australian coal-bearing rocks confusion may arise when *Vertebraria*, *Sphenophyllum*, and *Clasteria* are quoted as three different forms.

I have also to explain another case, the contrary of the preceding, *i. e.*, the correlation or identification of three different forms in comparing our coal strata with those in Australia: I mean the three forms, *Schizoneura*, *Zeugophyllites*, and *Nöggerathia.* A closer examination and comparison of these three forms shows that they are as different as the former three are identical.

* Royle, Illustr. of the Botany, &c., Him. Mount, 1839, tab. ii.

† Unger gen. et spec. plant. foss., 1850.

‡ Ann. and Mag. Nat. Hist., Vol. 20, 1847.

(*a*) *Schizoneura*, Schimp.—In this form the leaves (portions of the spath) consist of several leaflets, which are long and linear, and attenuated at both ends; by their connexion the spath is produced. Each of the leaflets is traversed by *one single* pretty thickish vein; and the spath, or a portion of the spath (leaf), shows as many single pretty thickish and pretty equally distant veins as there are leaflets joined together.

That the spath is produced by connexion of several single leaflets is shown by the many instances, both in the European Trias and in our Damudas, where the spath partly splits into the single and free leaflets. The stalk of this plant is articulated, and the spath in the joints is "amplexicaulis."

I have not found any drawing of an Australian plant which could be referred to *Schizoneura*.

The characters mentioned distinguish *Schizoneura* unmistakably from *Nöggerathia*.

(*b*) *Zeugophyllites*.—There are noticed two species of this genus: *Zeugophyllites calamoides*, Bgt., from India (Raniganj, Bengal); and *Zeugophyllites elongatus*, Morr., from Australia.

Brongniart, Morris, and Schimper, who very well knew the characters of *Schizoneura*, did not unite *Zeugophyllites* with this genus; on the contrary, compared it with quite other forms. Brongniart, the original describer, says in his Tableau des genres de végétaux fossiles, p. 89* about *Zeugophyllites*: "Sous ce nom j'ai désigné une forme de feuilles *pinnatifides* de Monocotylédones ressemblant à d'áutres feuilles de Palmiers, telles que celles des *Calamus*, des *Desmoncus*, &c., dont les folioles ont plusieures nervures principales et ne *sont pas pliées en carènes* sur la ligne médiane; dans la seule espèce de ce genre fossile les folioles sont opposées comme dans quelques *Calamus*."

Prof. Schimper thinks to recognise in this diagnosis one of the great *Pterophyllum* or *Anomozamites* from the Rajmahal Hills.

Of the *Zeugophyllites calamoides* no drawing exists; but we have a drawing of *Zeugophyllites elongatus*, Morr.† Supposing this drawing is correct (and there is no reason to think that it is not so), the great difference from any known *Schizoneura* must be seen: the veins are much more numerous, and they belong to the *leaf itself*, which is not composed of several leaflets. It recalls strongly certain *Cycadeaceæ*, especially *Zamieæ*, with which would also agree the circumstance, that of the Australian *Zeugophyllites* single detached leaves are so frequently found, while in *Schizoneura* the spaths seem to have been much more closely inserted in the joints. Amongst the fossil *Cycadeaceæ*, we find, especially with *Podozamites* and others, that the leaves are frequently detached.

That *Zeugophyllites* cannot be placed with *Nöggerathia* will be seen from the following:

(*c*) *Nöggerathia*.—Those specimens from the Damuda series which are styled *Nöggerathia*, and those which I have seen from the upper coal measures‡ of Australia, cannot be compared with either of the former two. The leaves of the so-called *Nöggerathia* are oblongly spathulate, sometimes oblongly ovately rhomboidal: the veins passing out from the attenuated base are thickish, and radiate into the leaf surface, several times forked. This character is at least exhibited in all the Indian specimens examined by me. It is evident that these leaves do not resemble either *Schizoneura* or the Australian *Zeugophyllites*; but neither can they be quite well united with what is described as *Nöggerathia* from the European coal measures.

* Schimper, Trait d. Pal. veget. II, p. 505.
† In Strzelecki, N. S. Wales, &c., tab. vi, fig. 5, 5a.
‡ Above the Marine Fauna.

My opinion is that the forms of our so-called *Nöggerathia* are all *Cycadeæ*, and especially *Zamieæ*, so that in future I will treat them as close to *Zamia*. We conclude therefore that—

(*a*) the Indian *Schizoneura*, is different from the Australian *Zeugophyllites* and the Australian *Nöggerathia ;* also from the Indian so-called *Nöggerathia :*

(*b*) the Indian *Nöggerathia* is different from the Australian *Zeugophyllites :*

(*c*) The Indian *Nöggerathia* is more allied to *Zamia* than to any other form.

XIX.—NOTE ON THE OCCURRENCE OF "GLOSSOPTERIS" (?) IN THE COAL-BEARING ROCKS OF ASIA MINOR, AND ON THE OCCURRENCE OF THE SAME GENUS IN THE TERTIARY FORMATION OF NOVALE.

In my notes on the Indian fossil floras, especially those from the Damuda series, I have made no mention of the supposed occurrence of *Glossopteris* in the coal-bearing strata in Asia Minor, nor have I found any mention of it in papers relating to our Damudas or to the Australian coal-beds, nor have I found it noticed in general palæontological works.

There is, however, a paper by Mr. Schlehan: Versuch einer geognostischen Beschreibung der Gegend zwischen, Amasry and Tyrla-Asy, 1852, where fossils are mentioned from the coal-deposits of Amasry. All these plants are genuine carboniferous plants, most of which are specially determined: amongst the ferns, *Glossopteris* is mentioned, but without any specific determination. It is indeed to be regretted that the names only are given, and nothing is said about the plants, and no figures are given, so that no idea can be formed as to the nature of this supposed *Glossopteris*. The carboniferous plants which Mr. Schlehan mentioned from Schünalü and Tyrla-Asy (Amasry district) are the following:—

FERNS.

Cyclopteris orbicularis ; Sphenopteris elegans ; Neuropteris gigantea ; Neuropteris tenuifolia ; undetermined species of *Sphenopteris, Pecopteris, Odontopteris.*

LYCOPODIACEÆ.

Lepidodendron aculeatum ; Lepid. obovatum ; Lepid. alveolatum ; Lepid. hexagonum ; Lycopod. pinnatus ; Lepidostrobus.

SIGILLARIEÆ.

Sigillaria oculata ; Sigill. alveolata ; S. sulcata ; Stigmaria ficoides.

EQUISETACEÆ.

Calamites Suckowi ; Calam. undulatus ; Asterophyllites ; Volkmannia ; Sphenophyllum majus ; Sphenophyllum emarginatum ; Annularia fertilis. With all these fossil plants of real carboniferous character, undetermined species of *Glossopteris* are mentioned.

As nothing has been published since about the collections of Mr. Schlehan, who is an Austrian Engineer, I thought it best to go direct to the source, and wrote to Herr Hofrath von Hauer, Superintendent of the Austrian Geological Survey in Vienna, to obtain some information about the supposed *Glossopteris*. I wrote on the 31st of July, and on the 6th of October I received a letter from Hofrath von Hauer, with another letter by Mr. Schlehan, in which he explains the case, and which shows that the determination of *Glossopteris* wants confirmation. To settle the question, it may be useful to reproduce some passages of Mr. Schlehan's letter to Hofrath von Hauer, and which this latter gentleman was so very kind to send me.

Mr. Schlehan writes (Oberlaibach, 8th of September 1877):—"As you perhaps recollect, I had the management of the opening of coal-mines in that region from October 1842 up to the end of 1843, and had therefore the opportunity of collecting fossils." These fossils, however, arrived in Europe to a great extent very damaged, so that only some of them were of any use. Mr. Schlehan writes further:—"The determination of the Petrefacta was made in Asia with assistance of Bronn's 'Lethæa geognostica' and Göppert's 'Systema filicum fossilium,' the only two works at my disposal there. The paper on Amasry and Tyrla-Asy was ready for publication already in 1844, but it was only published later in the German Geological Society through the aid of the long since deceased, and so deservedly lamented, Herr Leopold von Buch. If you now will take into consideration how many of the Petrefacta in 1842 had different names from at present, and how Palæontology has developed since the date when I went to Asia, it is quite possible that what I mentioned as *Glossopteris* has at present quite a different name."

Subsequently there are some notes by Mr. F. Fötterle on these coal-bearing rocks on the northern coast of Asia Minor,* where these rocks between Eregli and Amasry are classed as Permian, the following fossils having been asserted to occur: *Calam. gigas; Pecopt. Geinitzi; Odontopteris obtusiloba,* these being Permian species. No *Glossopteris* is mentioned. This classification of Mr. Fötterle may indeed, on account of the fossils mentioned, be considered as a correct one; and it is quite possible that, besides carboniferous, Permian is also developed.

But in his great work, Asie Mineure, 1867, Vol. I, Géologie, Mr. P. de Tchihatcheff speaks of these deposits again as carboniferous. The fossils, which he was fortunate to secure from between Eregli and Amasry, were submitted to the competent judgment of M. Adolphe Brongniart; and Mr. Tchihatcheff says, p. 709: "c'est un document important qui, pour la première fois, constate d'une manière rigoreuse l'âge des dépôts houillers situés entre Éregli et Amasry."

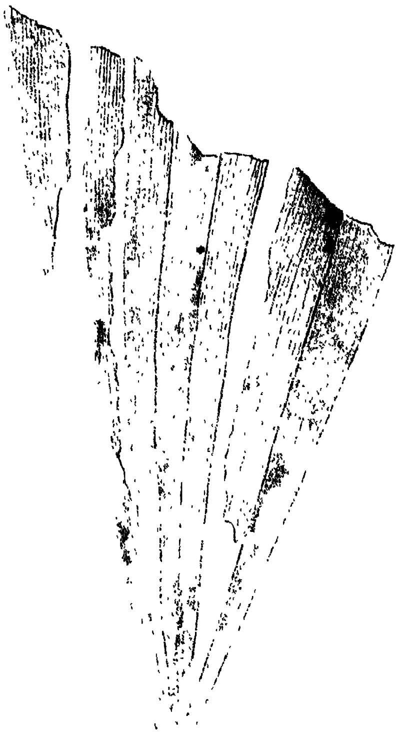
Mr. Adolphe Brongniart determined the following:—

Sphenopteris; Lepidodendron caudatum, Stbg.; *Lepidodendron,* near to *Lep. elegans; Sigillaria Candollei,* Bgt.; *Sig. Schlotheimi,* Bgt.; *Syringodendron pachyderma,* Bgt.; *Stigmaria ficoides,* Bgt.; *Lepidophloios; Calamites Suckowi,* Bgt.; *Calam. dubius; Sphenophyllum,* identical with the European species.

Adolphe Brongniart stated that this flora agrees most closely with that of the Rhine basin; but *no Glossopteris* occurred with these plants, which would have certainly been recognised by Brongniart, the original describer of the genus.

Quite recently, however, I observed in the Geological Magazine for July 1877, that a paper was read before the Geological Society by Mr. Spratt, entitled: "Remarks on coal-bearing deposits near Erekli, the ancient Heraclea,"† where, amongst plants of undoubted carboniferous type, as *Lepidodendron, Lepidostrobus, Calamites, Sphenopteris, Pecopteris, Sigillaria, Stigmaria* and *Sphenophyllum,* a *Glossopteris* is mentioned; but again as *Glossopteris* (?). We shall perhaps learn a little more about the impressions mentioned as *Glossopteris* (?) when this paper is fully published. We may notice, however, that the occurrence of *Glossopteris* in the Jabalpur group is not the highest extension at present known of the genus. In their Monograph of the tertiary flora of Novale,‡ Messrs. Visiani

* Jahrbuch k. k. Geol. Reichsanstalt, ix, p. 85.
† More generally known as Eregli.
‡ Mem. d. Acad. di Torino, IId Ser., vol. xvii.



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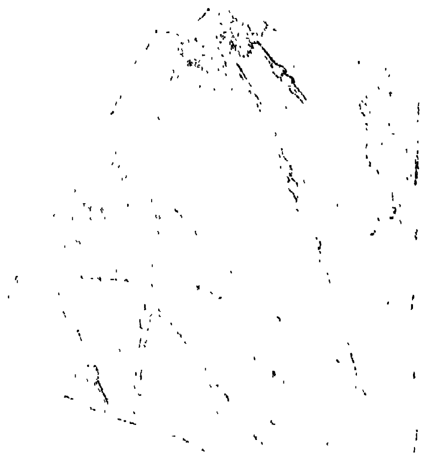

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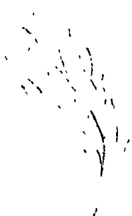

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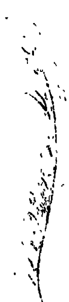

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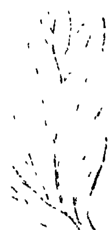

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and Massalongo have described, amongst the ferns, a *Glossopteris*, as *Glossopt. apocynophyllum*, on p. 206; and there is a figure of it on pl. I, fig. 1. There is, supposing the figure be correct, hardly any doubt that this form belongs to those ferns with a distinct midrib and areolated venation, which in India and Australia are called *Glossopteris*. It is a strange coincidence that with this *Glossopteris* of Novale broad-leaved species of *Tæniopteris* were found, with pretty distant dichotomous veins, which are as distant as in our *Macrotæniopteris danæoides*, Royle: they were described as *Tæniopt. affinis* Mass. et Vis., and *Tæniopt. crassicosta*, Mass. et Vis.; they, however, seem to belong to one species, which must be classed with *Macrotæniopteris.*

I shall now make some remarks on the affinities of *Glossopteris* with living forms, based mostly on the mode of fructification. In some of the Australian specimens Mr. Carruthers thinks he has observed a fructification *along* the *secondary* veins, which reminds strongly of *Anthrophyum*, with which also the areolation agrees; and already Prof. Ettingshausen* compared *Glossopteris Browniana* with *Anthrophyum Cayenense*, Spr., which is a form of that genus with distinct midrib.

Anthrophyum exhibits, however, with similar shape of the leaves, also forms with radiary net-venation, without midrib; and I have already pointed to this case, to show that, perhaps, at least certain forms of *Glossopteris* could be to *Gangamopteris* in the same relation as are the forms of *Anthrophyum* with midribs to those without midrib.

Amongst our Indian forms of *Glossopteris*, I think we have two states of fructification. One is that known in the specimens of Nagpur, which are the typical forms of *Glossopt. indica*, Schimp.; they show a fructification like that in the living genus *Polypodium*. Another form from the Raniganj coal-field I think shows some traces of a marginal fructification, and would recall the fructification of the genus *Pteris;* it is the *Glossopteris angustifolia*, Bgt. The fourth form is the tertiary *Glossopteris apocynophyllum*, of which no fructification is known; but Ettingshausen suggests that it belongs to *Chrysodium.*

Our knowledge of the living affinities of *Glossopteris* stands therefore as follows :—

Fossil.	Living.		Observed.
	Order.	Genus or species.	
Glossopteris Browniana, Bgt. ...	*Polypodieæ* ...	*Anthrophyum Cayenense*, Spr.	In Australia (Carruthers).
Glossopteris indica, Schimp. ...	*Polypodieæ* ...	*Polypodium.* ...	In India (Obs. Brongniart, Bunbury, &c.).
Glossopteris angustifolia, Bgt. ...	*Pterideæ* ...	*Pteris.* ...	In India (the author).
Glossopteris apocynophyllum, Mass....	*Acrostichaceæ* ...	*Chrysodium.* ...	Tertiary, Novale (aut. Ettingshausen).

There are, of course, many other specimens and forms in which no fructification or any other character to compare them with living forms has been observed. They can no doubt partly be referred to the above-mentioned forms; but there may still be different types.

* Farren der Jetztwelt, p. 25, 1867.

THE BLAINI GROUP AND THE "CENTRAL GNEISS" IN THE SIMLA HIMALAYAS, BY LIEUT.-COLONEL C. A. MCMAHON.

I.—THE SIMLA NEIGHBOURHOOD.

On my transfer to Simla from Hissar, the first thing I attempted to do in the way of geology, was to trace the outcrop of the Blaini* limestone round Simla; and I proceed to give as briefly as possible the results of my explorations. The Blaini rocks form such an important clue to the structure of the region around and beyond Simla, as was pointed out in the preliminary sketch of the geology of those hills published by the Geological Survey,† that it may be worth while to record a notice of its position as traced over a large area.

The most convenient starting-point will, I think, be the Lakri Bazaar, Simla. When I arrived at Simla, there was an outcrop visible on the mall, a few yards to the north of the Lakri Bazaar, and another below it on the road leading to Elysium. Following the mall round the north of Jako towards Mahásu, there is a good outcrop on the road side opposite the house called Snowdon, and the Blaini conglomerate is well exposed on the opposite or north side of the road. The limestone crops out again just below where the road to Mahásu branches off from the mall, and thence striking across the mall comes to the surface on a knoll above the house named Holly Oak at an elevation of 7,600 feet.‡ Still proceeding east along the North Jako road, a good outcrop is seen on the road side at the extreme north-east of Jako just where a path descends from the mall to the Mahásu road. Between this point and the exposure of the rock opposite Snowdon, the conglomerate may be seen in numerous places both on the North Jako road and on the Mahásu road below it.

From the point on the north-east of Jako, above alluded to, the Blaini rocks strike down the *khad* in a south-easterly direction and then curve round the flank of Jako, descending by a gentle but steady slope. The limestone passes just above the villages of Sanguti (elevation 6,929 feet) and Chanán (6,600 feet), the outcrop being almost continuous. Thence it winds round the flank of the Chota Chelsea spur above the village of Baláh, and onwards through Malkána and Kamháli to the east side of the Chota Simla spur. It then rises to the crest of the spur and crops out along the top of it until it overhangs some slate quarries. From this point the hills drop rapidly to the bed of the Ussan, and the Blaini rocks have been removed by the erosion which has carved out the valley of that river. The outcrop of these rocks, however, can be traced in a north-westerly direction down to the bottom of the ravine between the two spurs into which the Chota Simla spur bifurcates; and from thence in a south-westerly direction up the opposite side of the spur, being well seen at Chali, Laret, and Jharet.

A little distance beyond Jharet, at a temple above Kwalgarh, the Blaini rocks show again, and then they are cut off by a fault which runs towards the eastern boundary of

* I have followed the modern system of spelling adopted by Government within the last three or four years. The first vowel sound is hard, as in Blind.

† Medlicott: Memoirs, Geol. Surv. India, Vol. III, where the following classification is given of the rocks of this region:—

TERTIARY ...	Siwalik.	
	Nahan.	
	Subathu	Kasauli.
		Dagshai.
		Subathu (nummulitic).
	Krol.	
	Infra-Krol.	
	Blaini.	
	Infra-Blaini (Simla slates).	
	Crystalline schists and gneiss.	

‡ The top of Jako is 8,048 feet. Holly Oak is, according to the Trigonometrical Survey, 7,523 feet.

Jatog; and to pick them up again one has to cross the spur and descend into the gorge of the Sunal River which runs down from the Combermere Bridge, Simla, over the "Water-Falls" into the Ussan. The Blaini limestone shows first on the west side of this ridge under a house called Dâta, near the hamlet of Darmáchi, and thence in a north-westerly direction until it cuts across the bed of the Sunal under the village of Kwára. It is here seen typically resting directly on the Blaini conglomerate. The outcrop may be followed on the right or west side of the Sunal valley as far as Shail, but a little beyond this it is again cut off by the fault above alluded to. Following the line of strike from Shail, one comes on highly metamorphic schists of the Infra-Krol series, and all trace of the Blaini beds is lost. Lower down in the bed of the Sunal the line of fault may be clearly seen, the black carbonaceous Infra-Krol rocks, being on the left bank, brought into juxtaposition with the clear purple and greenish-grey Simla slates, with little disturbance of dip at the line of junction. Higher up the line of fault, the Simla slates have suffered violent contortion.

Descending the Sunal into the Ussan River the Blaini limestone is again picked up on the left bank of the Ussan at Kalog Bag.* Between Shail and Kalog Bag the intermediate rocks belong to Infra-Krol series. From Kalog Bag there are several exposures of the limestone in and adjoining the Ussan until a low southerly dip takes it below the bed of that river. Further on, a northerly dip sets in and rapidly becomes very high. The rocks are nearly vertical in the narrow gorge of the Ussan just below the junction of the Tandalail† stream. The Blaini *limestone*‡ is not exposed here, but the conglomerate is in great force. The conglomerate as seen here deserves, I think, especial study, as an acquaintance with it may lead to the identification of the rock at other places. There are several beds of it—some sparsely, others abundantly conglomeratic. The sub-angular or partially rounded blocks of slaty grit are absent, but the white quartz "eggs" are very abundant. Sometimes conglomerate is very fine-grained, and it probably passes into the Blaini quartzite sandstone. This variety of the Blaini conglomerate is at times much flowered over and pierced by white quartz-veins, and a person not familiar with the rock might easily be led to suppose that its peculiar appearance is wholly due to metamorphic action. A close inspection, however, shows that the rock is a true conglomerate; rounded pebbles of dark-grey or purple quartzite are sometimes freely scattered amongst the white quartz "eggs," and the former at times contain one or more thin white veins which do not pass into matrix, showing clearly that the metamorphism of the contained pebble was effected before it was worn down into its present shape and buried in the matrix.

Following the line of strike which leads at first along the crest, and afterwards along the flank of the spur that runs up from the Ussan River to the peaks above Kyari Ghât,§ the limestone crops out again at Badun. The dip is north-east down into the Tundalail, and the limestone is seen twice between Badun and the stream. In the bed of the latter there is about 60 feet of it, thin-bedded and nearly vertical. It is here, by local contortion, jammed into the dark Infra-Krol slates, and partakes of the colour of the latter.

Following the line of strike from Badun, the limestone is again seen between that village and Basna. Near Basna the black Infra-Krol rocks and Simla slates are seen together. Following the line of junction of the two rocks, I passed over the crest of the ridge and landed at the exposure of the Blaini limestone on the Simla and Kalka

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* A little west of Tharala of the map.

† This is the stream marked on the map as flowing down from Dhar, where it has its rise near the Kalka and Simla road, past Tundul of the map.

‡ In the slates at no great distance, there is a calcareous slaty bed.

§ Kyari Ghât is a Dâk Bungalow on the transverse spur a little to the north of Kura of the map.

road near Kyari Ghât (13¾ miles from Simla). About 100 feet in vertical height, below the cart road, the limestone crops out and is exposed for some little distance, and is then lost owing either to a sudden twist in the line of strike or a small fault. At no great distance, however, to the south-west of this point, it crops out again in great force in front of Wákna and shows along the path leading to Mamleg* for about half a mile, and is seen resting directly on the conglomerate. It then crosses from the south to the north side of the spur, and shows almost continuously down to the Chiama hamlets, where conglomerate of the Ussan type is abundant. The strike now becomes north-westerly, and the limestone shows abundantly through the several Chiama hamlets until it is lost in the cultivated fields overhanging one of the tributaries of the Gamber. From this point the Blaini rocks strike directly for the south end of the Syri hills, and though the limestone does not again crop up until the Gamber is reached, the conglomerate can be easily traced under and in immediate contact with the Infra-Krol slates. On the right bank of the Gamber the limestone re-appears, and beds of from 10 to 15 feet in thickness are repeated several times by crushing, the Infra-Krol slates being caught up in the folds. Above the limestone are the black slates of the Infra-Krol series, and below it the conglomerate in all its varieties in great abundance.

From the Gamber there is an almost unbroken outcrop of the limestone through Jabal-Bakesu and Khairi-Bakesu on to Mamleg. On the ascent up to Mamleg, the limestone gets astride on the back of an anticlinal that extends up to the Syri road, and consequently spreads out to a great width. At Mamleg and below it the limestone is seen in great profusion. The extension of this bed in a south-westerly direction would take it to the Syri road above Haripur. On the edge of the Mamleg plateau it is seen overhanging the intervening valley, and a limestone re-appears on the other side. It crops out near Dochi on the Syri road and along the crest of the ridge, and then dips under the nummulitic rocks, as represented by the pisolitic bottom-rock of the Sabathu group. I cannot be certain that this last described limestone (the Dochi bed) is the Blaini rock, but I think it is.

The north-westerly outcrop of the Blaini limestone may be followed from Mamleg until it nearly reaches the Haripur and Syri road. On the road side the conglomerate (the Ussan variety) is seen dipping south-west and north-east. The limestone continues under the road for some distance, until at last it cuts across it close to where a turn in the road brings the Syri Bungalow into sight for the first time. From this point (proceeding towards Syri) the outcrops on the road side are numerous. The limestone is also seen in cliffs below the road, being outcrops along its north-easterly line of dip. The conglomerate of the Ussan variety is here very abundant. The limestone forms the crest of the ridge where the road shifts for a short distance from the east to the west side of the ridge. It finally leaves the road about one mile from the Syri Bungalow, and strikes in a north-westerly direction. There is a constant outcrop through Báma and Barog to Chanog, and thence on to Sharar (Surair of the map), where I shall for the present leave it and return to Simla.

Following the line of strike to the westward from the Lakri Bazaar, the Blaini limestone is well exposed on the lower roads below the bazaar leading from Waverly to the Willows. It there strikes down the hill side and has frequent outcrops until hidden by the wood under the Union Church. It re-appears on the spur about 200 feet below Wheatfield, and from thence the outcrop is pretty continuous to the Simla and Bajji road, which it crosses at an elevation of about 6,500 feet. From this point its course is just under Annandale to the east side of the Yarrows spur, which it crosses at about 600 feet in vertical height below that house. It is well exposed again on the west side of this spur, and it

* Mamleg is a village on the western side of the little transverse ridge to the south-west of Hamahi of the map. A line drawn from *Sairi* through Hamahi would strike it.

crosses the Chadwick Hill spur at an elevation of about 6,250 feet above the sea. Frequent outcrops may be seen in its onward course, and it is exposed in the ravine about 120 yards below the Chadwick Water-fall. From this point the outcrop is frequent to the crest of the spur running north-west from the Chadwick Hill. The conglomerate is well exposed in some places in this vicinity.

The Blaini limestone is next seen not far from the village of Sarhog, then at Khil, and next in the ravine below Panti. Panti is on a spur running north from the extreme western point of Jatog. From the Chadwick spur the strike of the Blaini rocks is in the direction of the principal town of the Dhámi state, and consequently it crosses the range of hills running north from Jatog some miles from that station. At Dochi* there is a slight outcrop, the dark carbonaceous rocks being above, and the light coloured clay-slates below it. Its course is now *viá* Kansi, Salána, Bahl, Bitmána, Sar, and thence to Hallog, the capital of the little state of Dhámi. The Blaini rocks cross the ridge about half a mile or so to the north of Hallog, and then curving round in a south-westerly direction are exposed on the western flank of the ridge. The limestone shows well in fields 100 to 150 yards below the village of Ghurrap on the Hallog (Dhámi) and Bajji road; again typically at Piroi; and again on the spur below Piroi to the south-west. The outcrop at the latter place is interesting, because not only are blocks of dark slaty blue limestone seen close to masses of a dirty pink colour, but variegated blocks may be seen, the two colours being exhibited in patches side by side. Between the last outcrop and Pallaini-ka Ghât the Blaini limestone shows in six or seven places. It then cuts across the Dhámi and Arki road at a place called Roh-ke Khal.† It shows profusely under the road, and thence on to Giatu, and further on at Pori, near which village it cuts across the Simla and Arki road. There is no exposure on the road side, but it is seen in the stream (*in situ*) under the road near where the latter crosses the crest of a ridge running down from the Marang hill. The strike is here south-15°-east, and there are several exposures between the last-mentioned outcrop and Jamrog, where it also shows. Its course is now *viá* Bándla, Patti-ke Ghât, Ghach (Gach of the map), and Kaliana to Sharar (Surair).

From Sharar a branch makes for the hills above Haut. There is a good exposure just above the Koni River near Bánjan, about 2 miles above Bil. It shows abundantly from this to Chakniat and onwards to Ghât on the Syri and Haut road. Its course is now south-20°-west. It forms the crest of a ridge running south from Ghât and then appears in cliffs above Chabal. The Blaini limestone shows on a knoll at Shág, and the conglomerate on a spur further on. The outer outcrop keeps to the edge of the hills bordering the Dún. It is exposed typically in a stream under Baráwari with the conglomerate below it to the west; dip nearly vertical; strike south-22°-east. An upper outcrop above this forms cliffs under Paniáli; caps two knolls above Gori, and forms the crest of the hill on which Patta (the residence for many years of the present Raja of Suchet) is built. At Patta the dip is nearly flat. The limestone is 27 feet, and the conglomerate on which it directly rests is about 40 feet thick. The latter contains oblong boulders 22 and 23½ inches long, and in this respect exactly resembles an exposure on the North Mall, Simla. The conglomerate here is quite typical, but all along this line there is a good deal of the Ussan type also. An extension to the east would take us to the limestone on the crest of the Syri ridge near Dochi alluded to above.

I may note in passing that the conglomerate is always *below* the limestone: apparent exceptions may, I think, be readily explained.

* There are two villages of this name, one north of Jatog, and one near the Syri road.

† Between Gobog and Dhardi of the map.

Following the lower outcrop from Baráwari the limestone shows at a temple (Bijesar Mahadeo), and from thence the outcrop is frequent, and runs *viá* Thana and Patru to Parála* on the Syri road just above Haripur. The dip is here high easterly, nearly perpendicular. The Sabathu Nummulitics are caught up in a fold of the Blaini rocks which show on either side of them on the Haripur road. The last outcrop of the Blaini limestone on this road is about 300 yards north of the Bungalow, and in an excavation on the crest of the ridge at this spot I found the conglomerate.

From this section, and from another between the Blaini River and the Boj range, I conclude that in *some cases* the Infra-Krol rocks were *totally* denuded before the Nummulitics were laid down. The course of the Blaini rocks to the Blaini River has been already described (*l. c.* p. 31).

In the above pages I have simply described the line of outcrop, but I need hardly say that I have tested my work by examining the rocks above and below the Blaini group. A few general remarks may not be out of place. From the Blaini rocks at the Lakri Bazaar, Simla, there is an apparently unbroken succession of the Simla slates to Naldera (the ridge above Bassantpur), where the limestone series of the Sháli mountain and the Satlej valley begin. The dip is steady, and there is not the slightest trace of an anticlinal. From Dhámi the rocks under the Blaini are the Simla slates, and they extend down until one comes abruptly on the massive limestone of the Satlej valley. From the Blaini rocks on the Simla and Arki road, the Simla slates extend down to the limestone series at Arki. The dip, very moderate at first, soon becomes high, and near Arki vertical.

Regarding the inner (*supra*-Blaini) area I note that the Krol rocks at Jatog are succeeded by the Infra-Krol schists in the downward section, and as the Blaini rocks are neared, the black Infra-Krol slates show prominently whatever direction is taken. Passing from Jatog to Simla the extension of the fault alluded to at page 204 brings up the Boileaugunj schists (Krol quartzite altered), but on the top of Prospect Hill (Simla), and on its west side, there is a dark carbonaceous limestone which, I think, must be one of the bottom beds of the Krol series.

The Jako rocks are, I believe, Infra-Krol. I think this series is about 3,000 feet thick, and that at the Krol and at Jako it either thinned out, or suffered denudation before the Krol series were deposited. Some sections on the flanks of the Chor suggest this view, but to confine myself to the area under description, I would point to the mountain† between Tára Devi and the hills above Kyari Ghát. The foundations of a ruined fort called Mán Ghât exist on the top of it. There are dark carbonaceous slates near the summit, and from the top down to the Blaini beds in the Ussan River the rocks belong, I think, to the Infra-Krol series. There cannot be less than 3,000 feet of them.

The stratification of this mountain belongs to the normal Simla type, *i. e.*, the dip is comparatively flat at the top, whilst the dip into the mountain increases on the flanks. In the river beds the normal condition is for the strata to exhibit indications of violent crushing; the beds being usually vertical and contorted. I have rarely struck the Blaini limestone in the bed of a river without finding it repeated several times by contortion. I am aware that other reasons might be given to account for this normal feature in the Simla area, but I think it may best be explained by the supposition that the present outline of the hills was to a considerable extent carved out before the last series of disturbances took place (as has, indeed, been independently shown, *l. c.* p. 174). This view would, it seems to me, explain the converging dip seen at the Chor, Krol, and elsewhere, as well as the extreme crushing in the low valleys.

* Between Banalag and Kisu of the map.
† On the atlas map a dotted line is drawn down this ridge from the cart road past Shongal to the Ussan River.

The notion might be best explained by a diagram, but it is quite intelligible in words: if a horizontal pressure be set up beneath a deeply eroded surface, any yielding that occurs would be determined along the lines of erosion, as positions of least resistance, comparative rigidity being maintained elsewhere by the weight of the mountain masses. We should thus have extreme contortion in the valleys, extending in diminishing degrees up the flanks of the mountain to the summit, where there would be a minimum of effect. This view would apply to the "transverse" as well as to the "longitudinal" valleys, for in a yielding mass any pressure becomes quaquaversal. The view is, no doubt, opposed to what is often stated in geological text-books, even of recent date, as a sort of axiom—that the contortions observed in strata must have been produced far beneath the surface; but it has been long since shown, in this very neighbourhood, that the extreme disturbance exhibited in the enormously thick Siwalik rocks must have been produced at the immediate surface.*

I think, then, that the converging dips seen so often in the Simla area, accompanied by a rapid increase in the angle of the dip as the valleys are neared, indicate that when the last great disturbance, which has left its marks so deeply on the Simla Hills, took place, the hill area had been approximately carved out into its present outline.

II.—JUBAL—TAROCHE—CHEPÁL.

The best starting-point for our next excursion will, I think, be the top of Kuper peak, in which the Giri takes its rise. A path from Jubal to Chepál passes some hundred feet below the top of the Kuper, the path rising to an elevation of 10,650 feet above the sea. The rocks exposed along the highest part of the road are the schists *above* the "central gneiss." Along the ascent from Jubal, the dip is about north-east; near the top it is north-11°-east. On the south side where a spur branches off in the direction of Chepál, there is a sudden change in the dip to south-east-11°-east,† and this change brings up the central gneiss at an elevation of 9,620 feet.

I hope to show hereinafter that this is the so-called "central gneiss," but for the present I only announce the fact.

As the slope of the hill side coincides with the dip, the path down to Bamlo (Bomta) runs over the gneiss all the way with the exception of two or three comparatively brief intermissions where the infra-gneiss mica-schists crop up. Bomta is at an elevation of 8,000 feet, and the gneiss shows as far as that village. My political duties required me to visit Taroche (Tirhosh), and the path from Bomta led me in a north-easterly direction down to the bed of the stream. On leaving Bomta, the dip rapidly veered round from south-11°-east to north-east, but the change is masked by grass and trees. In the bed of the stream I came upon thin-bedded calcareous schists utterly unlike the crystalline rocks I had left behind at Bomta. In the light of facts to be subsequently detailed, I do not think I shall be wrong in calling these calcareous schists Krol rocks.

The path up to Taroche (Tirhosh) soon led me above these rocks (below them stratigraphically expressed), and I passed through mica-schist (answering well to the Infra-Krol series) all the way to Tirhosh. After occasional local wavering to the north-north-west the strata settled down to a low north-11°-east dip. The stream below Tirhosh was full of the "central gneiss" boulders, showing the presence of that rock on the southern flank of the Kanchu peak.

From Tirhosh (elevation 6,950 feet) the road to Chepál makes an exceedingly steep descent (some 3,000 feet, I should say) to the stream flowing down from the Kanchu peak.

* Medlicott, 1868: Quar. Jl. G. S., London, Vol. XXIV, p. 47.

† I have not, in any of the bearings I give, made allowance for the variation of the compass.

Dip a little to east of north-north-east. The rocks were at first earth-coloured mica-schists of the ordinary Infra-Krol type, and latterly they passed into a dark bluish carbonaceous slaty schist with a very dark streak. The road now mounted obliquely the eastern side of the spur, running down from the Kanchu peak towards Chepál: and a good way up it, I came on a conglomerate strangely like the typical Blaini rock. Further on near Sartara (not marked on map) I came on limestone reminding me of the Blaini rock. Having crossed the spur, I descended along its western side towards the Simla and Mussurie road, which the path I followed struck between Chepál and Kadi. About two-thirds of the way down to the stream, I came on numerous large boulders of undoubted Blaini conglomerate. I climbed the hill in search of the outcrop, and though I could not find the conglomerate *in situ,* I came upon a limestone answering to the Blaini. It is pink and of a pale bluish-grey. Like the typical Blaini* it is a magnesian limestone, the pink variety containing 34·6 and the grey 28·3 per cent. of carbonate of magnesia.

The next day I searched up the bed of the river for a good exposure of the Blaini rocks, and was fortunate in finding one on the east bank of the stream just opposite where the descent from Chepál terminates, and the Simla and Mussurie road strikes the west bank of the river. I found the conglomerate resting on slates (Simla slates) with a pale grey streak. Resting directly on the conglomerate was a blue thin-bedded limestone from 20 to 30 feet thick; whilst on the latter rested the black Infra-Krol slates with a black streak. The conglomerate here is remarkable for the partial metamorphism it has undergone. The matrix, more of a schist than a slate, is internally of a light grey colour, but it weathers to a dark bluish-grey. The boulders of what would in the Simla section be the slaty grit are here a quartzite, of various sizes and shapes, ranging in colour from white to pink and to a dark grey. The conglomerate is flowered over with white quartz-veins, which occasionally penetrate the contained boulders as well as the matrix. I have noticed instances of this in the Simla section.

From a careful study of the outcrop exposed in the bank of the river, I think it is beyond all reasonable doubt that the rocks there seen are the Blaini rocks. The limestone and conglomerate seen on the previous day on the eastern side of the spur being in the line of strike with the rocks exposed in the river and on the western side of the spur, must also be the Blaini rocks. The limestone crops out on the west bank of the river, and may be traced up to the Simla and Mussurie road. Beyond this I had not time to trace it. I dare say it runs a short way up the valley of the river which (*vide* map) flows down from the Chor past the southern base of the Chepál spur into the Shallu River.

Before taking leave of this section, let us visit Chugna (Khagna) at the head of one of the branches of this river on the south-west side of the Chepál spur. It is at an elevation of 6,900 feet, and is not less than 3,000 feet in vertical height above the outcrop of the Blaini rocks in the Shallu River just described. Serai (Serañ†), which is nearly south of Khagna, is 7,250 feet above the sea. The dip is flat between the two places, but at Khagna a low north dip sets in. On the Serai road, about 2 miles from Khagna, there is a band of dark-blue limestone of no great thickness which may be traced a long way towards Serai,

* I analysed two specimens selected at random from two typical exposures in the Blaini River with the following results:—

No. 1.		No. 2.	
Silica	8·6	Silica	8·3
Iron	5·9	Iron	5·4
Carbonate of lime	49·9	Carbonate of lime	49·7
Do. of magnesia	36·4	Do. of magnesia	35·8
	100·8		99·2

† Seran (silent n) is a demon who resides somewhere in the Chor. Our Mahomedan Munshis always write it Serai, and suppose that the word means a resting-place for travellers.

and which must, I think, be a Krol rock. Below it (I examined the descending series for about 1,500 feet in vertical height) are carbonaceous shaly schists and slaty schists which become somewhat chloritic. Above the limestone are silicious and garnetiferous mica-schists, which possibly belong to the "central gneiss" or crystalline series of rocks, and if so, we have here an instance of the extreme unconformity I believe to exist between these two great divisions of our rock-series.

I return now, after this digression, to the Blaini rock left in the Shallu River 3,000 feet below. The Blaini beds there dip north-west at a considerable angle and are repeated two or three times by contortion. On the ascent up to Chepál, the dip drops to 15° north-11°-west and north-north-west. At Chepál the dip is north. The rocks on the Chepál, Paternalla (Patanála) and Daha (Dhár) ridges, along which the Mussurie and Simla road winds, have been conjecturally identified (*l. c.* p. 41) as the Infra-Krol and Boileaugunj (Krol quartzite) series. If this view is correct, and I feel sure it is, the Blaini rocks must pass under these schists and ought to crop out between Dhár and the Giri. Accordingly where the road crosses the Chota Nadi (the stream which flows down from Patanála past Ghodna to the Giri), I observed numbers of boulders of the Blaini conglomerates in the bed of the stream.

I availed myself of the first opportunity I could get to search the bed of the Chota Nadi for the Blaini rocks, and I found that the conglomerate cuts across its bed about 2 miles above the bridge on the Dhár and Simla road. The conglomerate exactly resembles the conglomerate below Chepál. There are the large pebbles or boulders of the dark quartzite answering to the slate-grit of the Simla sections; and there are the white quartz eggs which in this section at times, as in the Ussan River, form a prominent feature of the rock. Not far from the conglomerate I found a thin bed of limestone. From this point the conglomerate crops out freely, rising gradually from the river, and rounding the spur facing Tikera* (Sanj), whence its course is up the left or east side of the valley of the Giri, I met several outcrops of limestone along this section. I left the conglomerate in cliffs high up on the east side of the valley, and as it was clear from the run of the strata that it must soon strike down to the Giri, I continued my search for it along the bank of that river. I found that it cuts across the Giri about 1½ miles on the Sanj, or south, side of Bagain. The slates are here perpendicular, and those on both sides of the conglomerate have a black streak which appear to indicate that the Blaini rocks have been jammed into the Infra-Krol slates. The boulders in the conglomerate are well rounded, and in places are so loosened by the action of water that it required a careful inspection of the rock to satisfy me that I was not looking at river boulders entangled in cracks in the slates; but after a deliberate examination of the rocks, I felt satisfied that I had got hold of my old friend. Above the conglomerate the rocks are dark slates, till about one-third of a mile beyond Bagain,† where mica-schists begin. After this there are mica-schists and silicious schists all the way to Kot (Kot Khái‡). They are an exact counterpart of similar rocks at Simla, and clearly belong to the Infra-Krol and Boileaugunj (Krol) series. The average dip is east-north-east, sometimes 34°, at other times low. Below the conglomerate the rocks are Simla slates all the way along the road to Tikera (Sanj).

III.—MÁHASU, MATTIANA, AND SHALI HILLS.

Our starting-point for this excursion shall be Thiog. The old Mattiana road rises to the fort of Thiog (a fort on a peak to the north of the Dâk Bungalow), keeps along the

* There may be a village of this name, but Sanj is the name by which this halting place is known to Natives and Europeans.

† Bagain is on the road somewhere between Shilo and Choal of the map.

‡ Kot Khái is the principal town of the tract of country marked Kot Khai in large letters in the map. *It is on* the upper Giri.

crest of the ridge, and then passes to the east of a mountain-top that rises beyond. The Hindustan and Tibet road runs at a lower level on the western side of this ridge; a spur, called Kaleri-ki-Dhár, runs nearly due east towards the Giri. On the crest of this spur the Blaini conglomerate crops out (dip 24° north-east-11°-north). It is the counterpart of the outcrop below Chepál. Where first struck, it would require an eye trained to the Blaini rocks to identify it, for it is much overgrown with lichen and flowered over with quartz-veins. Further along the ridge it is more easily recognised, and the white quartz eggs are abundant. Though the matrix is hard, I was able in some cases to extricate the rounded boulders of quartzite almost entire. The matrix is of a whitish-grey colour and of schistose texture, and, in some blocks, the pebbles and boulders are so abundant that it was difficult to get good specimens of the matrix. Here, too, some of the quartzite pebbles are traversed by fine quartz-veins that do not extend into the matrix. One large block of rock I found with one face smoothed down and polished so as to show beautiful sections of the white quartz eggs which were abundant in the slab. This is undoubtedly the Blaini conglomerate, and it is *in situ*. The outcrop coincided with the crest of the ridge for a little distance, and then edged away from it down the flank of the spur. The strike of the bed would, if followed down the precipitous descent to the Giri, lead to the outcrop on the bank of that river already described.

In the opposite direction the line of strike would lead to the Hindustan and Tibet road somewhere near the 20th mile from Simla, but the line passes through a forest and I have not noticed any outcrop. Below the conglomerate (*viz.*, in the direction of Thiog) for some little distance, the rocks are slates (Simla slates) with a light grey streak. Dip east-north-east. Above the conglomerate are the Infra-Krol slates. Some of the latter are quite black. Following the road towards Mattiana, the Infra-Krol schists dip at first north-east 39°, but they subside into a low north-east-11°-north dip. These schists lead up to and dip under a strong band of quartzite which begins to show where the road rises to the crest of the ridge. This can be none other than the Krol quartzite.

Some distance further on, the Hindustan and Tibet road passes over to the western side of the ridge, whilst the old road, still used by pedestrians, keeps to the eastern side. We will follow the old road. The rocks exposed are quartzites and silicious, slaty, and micaceous schists, until about 2½ miles from Mattiana, when a bed of bluish-grey limestone, about 3 feet thick, crops out. Dip east-north-east. As Mattiana is neared, the schists become feebly calcareous. A little beyond Mattiana, they pass into calcareous chloritic schists, and in the line of cliffs facing, and some two or three miles beyond, the Dâk Bungalow, these schists become full of iron pyrites, generally in the form of minute cubes. These calcareous chlorite-schists contain from 6 to 14 per cent.* of carbonate of lime. The variety full of iron pyrites is a very curious rock. From the partial segregation of the calcite and the chlorite it often assumes a highly foliated structure. There are also numerous veins of white calcite in it. It weathers a deep brown. It has dawned upon me latterly that these rocks, and there is a considerable thickness of them, must be the Krol limestone *highly altered*.

But to return to the Blaini rocks. There is a thin bed of limestone on the top of the cliffs above Runi. The point is called Tikka. Elevation 9,280 feet, dip north-east-11°-north. The temple (Nág Devi) there is marked Kolu temple on the map. This rock is a magnesian limestone, and rests on a bed greatly resembling the matrix of the typical Blaini conglomerate. Under it is a quartzite band which forms a line of cliffs. Below Tikka there is a village on the map named Barana. A little distance to the east of this village, I came upon an extensive outcrop of conglomerate of the typical Blaini River type. Associated with it was a strong quartzite and a dolomite containing 33·8 per cent. of

* I was careful to select fair specimens for analysis that would not show an unduly high percentage.

carbonate of magnesia. Dip east. These rocks seem in the line of strike of the conglomerate at Thiog, and I think they must be the Blaini rocks. I may here mention that north-west of Thiog and 1,600 feet in vertical height below the Dâk Bungalow, I found a block of the Blaini conglomerate of Thiog type (whether *in situ* or not I cannot say) in the bank of the stream close to a thin-bedded limestone dipping north-north-east. In the bed and bank of the stream little below this is an intrusion of trap of the Mandi type.

In the opposite direction from Thiog, *viz.*, near Sanj (Tikera of the map) there is also evidence of the Blaini group. Sanj is as nearly as possible 3,000 feet below the Thiog Dâk Bungalow. On the crest of the hill overhanging, and a few hundred feet in vertical height above Sanj, is limestone. Below the latter are the Simla slates. On the road from Sanj to Fágu, as long as the road clings to the flank of the spur running down from Thiog to the Giri, I saw numerous blocks of the Blaini conglomerate on the hill side, indicating its presence somewhere above. Further on, on the next spur, there are numerous outcrops of limestone resembling the Blaini. On the ascent up to Fágu, the dip is about north-east. These outcrops correspond with the horizon of the outcrop of the conglomerate on the opposite or east side of Giri valley.

Now a word or two about the Shâli. This great limestone series extends from the Shâli to the Fágu and Thiog ridge. On one occasion I followed the line of the Nowle Gad* River from the two Daoti villages up to Thiog, and I found massive limestone cliffs of the Krol type on both sides of the valley, extending, as far as I could judge, right up to the Fágu-Thiog ridge. Along my actual route limestone beds cropped out continually all the way up to Thiog. Following the Hindustan and Tibet road from Fágu, these limestones crop out over the road about 1½ miles, from the Fágu Bungalow, and the outcrop is from this point pretty continuous for about 2 miles. In one place the limestone forms a cliff on the crest of the ridge. It is greatly crumpled, and seems to have been subject to enormous lateral pressure. Thin-bedded slaty limestones appear again in the road side-cutting a quarter of a mile beyond the Thiog Dâk Bungalow, and show well where the old Mattiana road branches off. They crop out frequently on the road up to the fort, and that structure is built on them. From this point they cut down in the direction of the Shâli and are seen on the sides of the Hindustan and Tibet road a little beyond the 19th milestone. These rocks may be seen forming cliffs below on spurs extending towards the Shâli. On the eastern side of the Thiog Fort, they crop out for some distance (about a mile) along the ridge running down to the Giri and form cliffs under Janti Devi, a temple which crowns a point on this spur. I did not encounter them after this on my way down to the Giri.

Proceeding from the Shâli in a direct line to Simla, the limestone extends across the Nouti, and crops up for a considerable distance on the spur, up which the road to Mashobra† winds, and then they suddenly give place to the Simla slates. I explored the ravine running down from Mahásu, between the two Daoti villages to the Nouti until stopped by impassable cliffs. The average dip is 20° to 23° south nearly all the way down. When the Nouti is neared there are indications of intense crushing, and then the rocks turn sharp down to a northerly dip, and from this point to the Nouti they continue to dip at a high angle. In the descending sections at first are the Simla slates; then comes 80 or 100 feet of pale blue or greenish limestone; under this are dark schistose slates with strings of quartz in them (a very common feature in the Infra-Krol schists), and then the black "crush rock." Thin-bedded blue limestones follow; the dip then gets flat; there is evidence of great crushing, and then the black carbonaceous rock re-appears with white calcite irregular veins in it. This

* Probably a misprint for Nouti, the name by which I found the river known on the spot. Gad seems to be the corruption of Gar, the vernacular word for river.

† Mashobra is the bazaar on the neck of the spur that runs north-west from the Mahásu spur to the Satlej.

rock is here a dense slaty rock almost as black as coal. The section above described strongly suggests the idea of a fault.

This leads to the important question, are the Sháli rocks Infra-Blaini or Krol? It might seem at first sight to follow from many of the facts I have recorded that these rocks are Infra-Blaini. If the Sháli were Infra-Blaini then our sections would run thus—

SIMLA	Prospect Hill	Krol.
	Boileaugunj	Krol.
	Jako	Infra-Krol.
	North Jako Road	Blaini.
	Mahásu	Simla slates.
	Fágu to Thiog	Sháli beds.
	Thiog to Mattiana	Simla slates. Blaini series. Infra-Krol. Krol.

In such a section the anticlinal would be required in the Sháli beds and would be drawn from Sháli to a point between Fágu and Thiog. There are serious objections, however, to the adoption of this interpretation which I am not able to get over. In the first place, the axis of the anticlinal must be drawn, if drawn at all, from the Simla end of the Mahásu ridge to the top of the Sháli: *2ndly*, whilst we have a great thickness of Simla slates at the Simla end of the section, there does not appear to be a corresponding thickness at the other or Mattiana end: and *3rdly*, we should after all have to summon a fault to our aid to get rid of the damaging fact of the presence of the Blaini rocks at Sanj and to the north-west of Thiog.

The alternative interpretation—the adoption of the Sháli rocks as Krol—*necessitates*, however, the belief in the existence of a fault between the Sháli and Mattiana (somewhere near Runi); in another between Náldera (the ridge above Basantpur) and Simla; and in a series of faults, or a sort of circular fault, in continuation of the Náldera fault, running round to Arki, and probably on to Kakkuhatti! It is rather appalling to have to adopt such a theory, but I do not see my way out of it.

IV.—NARKANDA—KOTGARH—RAMPUR.

In my last we travelled as far as Mattiana and for a few miles beyond. From the point we then reached to Narkanda and on to Kotgarh, the schists, micaceous and silicious, are somewhat undeterminate in character, but looked to me more like the younger series than the old. A few hundred feet—500 or 600 it may be—below Kotgarh, there is a thin band of blue limestone which extends for some distance. Under it and down to the stream that divides Kotgarh from Kumharsen, the rocks appeared to be the carbonaceous, micaceous schists of the Infra-Krol series. The dip at Kotgarh is low and northerly, but wavers about from north-north-east to north-west and even more westerly. On the road down to Kapu (Kepu) (on the Satlej, due north of Kotgarh), some of the cultivated fields near Shawat have that peculiar black soil so often seen in the Simla section in the neighbourhood of the black "crush rock." I observed this feature in other places in this direction. As the Satlej is neared we come first on mica schists and then on the "central gneiss." At Kapu (elevation 3,125 feet), the dip of the gneiss is 40°-north-11°-west.

Following the other road from Kotgarh to the Satlej, *viz.*, that to Nirth, we have first slates; then carbonaceous slates; then the gneiss alternating with slates. From Nirth to the Nogli, which flows into the Satlej a few miles south of Rampur, we have slates alternating with the gneiss; sometimes one showing, sometimes the other. Regarding the slates

I noted in my journal, when as yet I had formed no theory,—"They are often carbonaceous, and closely resemble the slaty schists above the Blaini rocks."

From the Nogli to Rampur and beyond, there is an extensive intrusion of trap which has tossed the rocks about a good deal. From Rampur to Nirth the dip, at first westerly, changes to east, then to south, and then back again to west.

Following the upper road from the Nogli to Narkanda, on rising from the Satlej, we come on white quartzite, then dark carbonaceous slates and schists, and in these, a little under Kumsu, there is a thin bed of blue limestone. It is not crystalline. A little above Kumsu the "central gneiss" begins. Again on this road, just below the Sungri Bungalow (on the ridge near Shimál of the map), on the northern side of the ridge, a blue sub-crystalline limestone appears. The outcrop being in cultivated fields, the immediate "allure" could not be made out. Elevation of Sungri, 8,675 feet.

The facts to be stated further on have an important bearing on the question of the nature of the contact of the Krol with the older crystalline series, but I think it will be more convenient to discuss that question now. The view I have formed is that the Krol, Infra-Krol, and Blaini series were laid down on a denuded surface of the crystalline rocks, and that the line of contact has been masked—

(*a*). By the subsequent metamorphism of the younger rocks, at the point of contact, in the *wet* way;

(*b*). By the subsequent compression of the two series against each other.

That the younger rocks often appear to be conformable to and to dip under the older rocks I fully admit, but is it *possible* that this conformity can be real? Are we to believe in an inversion extending along a great part of the line of the Himalayas? Or are we to believe that the "central gneiss," and at least 6,000 feet of mica schists on the top of it, are really younger rocks than the Simla slates? If they are, by what means has the metamorphism of the younger rocks been accomplished? Heat, the product of pressure from above, and heat, the result of plutonic action from below, seem to be put out of court, by the fact that the *lowest* rocks which ought to have been the most changed are the least altered.* Metamorphism in the wet way seems to me equally out of the question. Can we suppose that during the vast ages required for the gradual metamorphism, by the slow wet process, of the great thickness of strata we have to deal with, the Simla slates would have remained as unchanged as we see them at this day?

But may not the observed facts be rationally explained in the way I have suggested? A glance at the map will show—and I hope to explain this in detail further on—that the dip of the older strata is often low, and at times perfectly flat. It does not seem to require a great demand on our imagination therefore to suppose that the younger rocks were laid down upon and against the flat strata of the older rocks; and if the plane of junction of the two series were often more or less steep, would not the subsequent compression of the two together lead to the idea of conformity, especially if the younger rocks at their point of junction with the older had been considerably metamorphosed? That the Krol and Infra-Krol rocks have, as a matter of fact, undergone extensive metamorphism has been pointed out by others (*l. c.*, p. 34); and that this metamorphism has been produced in the wet way is indicated by the fact that it is extensive in the porous top schists and stops short at the impervious clay slates.

* Heat, the local product of tangential pressure, seems to have been *left* out of court.—H. B. M.

V.—SHANKAN AND HATU RIDGES.

In Section II we got as far as Kotkhai. I will make this our new point of departure. The road from Kotkhai (elevation 5,790 feet) passes over the Shankan ridge* at an elevation of 9,500 feet, and then drops down to Deora (elevation 6,600 feet), the capital of the Jubal state. The dip at first north-east changed to east-north-east, and then back again to north-east. The angle of dip, generally low, became flat at Deora. About a mile on the Kotkhai side of the Shankan ridge, a thin bed of "central" gneiss appears. Between it and Kotkhai, mica-schists, and occasionally silicious schists, prevail. I found it impossible to say where the Krol (Boileaugunj) schists and the Infra-Krol rocks ended and the crystalline series began. As far as outward visible signs went, there seemed no break in the conformity of the two series. On the crest of the ridge, I found a very thin bed of slate with a dark streak which seemed carbonaceous. I have observed this feature in other places well within the area of the crystalline rocks. These outcrops always seemed very thin, lenticular and local. Down to near Deora, the rocks are fine-grained mica-schists. One bed above the gneiss seems to retain its character all over the crystalline area. It is a fine-grained mica-schist that splits readily into large slabs, and is much used for roofing purposes. One slab I measured—and I give it as a fair sample—was *one inch* thick by 5 feet 8 inches long and 4 feet 2 inches wide. Viewed edge-ways, quartz seems to predominate, whilst the flat splitting face presents an unbroken surface of mica. On the descent there is a strong dyke of trap, the exact counterpart of the trap near Banellah on the flank of the Chor. As Deora is neared we come on the central gneiss, which is here a bed about 50 or 60 feet thick. It runs right round the head of the Deora valley, as indicated on my map.

The principal characteristic of the "central" gneiss is that it is always more or less porphyritic. In its lowest form the crystals are small and lenticular. As the metamorphism advances, they become large and eye-shaped: in the next stage, they take the form of blunted cubes. The next advance is to assume a perfectly rectangular form. These crystals are usually *about* 1½ inches long, but sometimes (as in the Chor), they attain a length of nearly 3 inches. As the metamorphism advances, the axes of the crystals begin to point at an angle to the plane of foliation, and the angle gradually increases up to a right angle. Finally, they point in all directions, and all trace, or nearly all trace, of foliation is lost. When the rock arrives at this stage, all signs of bedding disappear, and the gneiss weathers out into large rounded masses after the fashion of true granite, and becomes very dense and hard to break. The porphyritic felspar crystals appear to be orthoclase; twin crystals are not uncommon. An intensely black mica is another characteristic of this rock. It is a variety, I think, of Biotite. It takes no notice of concentrated sulphuric acid (cold), but continued boiling in this acid extracts all the iron of which the colouring matter consists. The rock also contains a silvery mica which is usually quite subordinate to the other.

We will now leave Deora for the present and return to Kotkhai. Our route thence will be up to Deori, the capital of the little state of Kanati. From Kotkhai to Deori the dip is east-11°-north, then north-east, then east-11°-north again, in mica-schists and silicious schists. On one occasion I went by a direct mountain path from Deori to Deora. I struck the "central" gneiss above, and to the east of Deori, and again just above Deora. The bed passes under the mountains from the one point to the other. The outcrop in the Kanati (Deori) valley takes the form of cliffs, and can be followed by the eye right round the head of the valley. My last trip in this direction was up to the head of the valley, and along the ridge which crowns the valley, to Bági and on to Narkanda. I struck the gneiss just above Thanári (Tharan, I presume, of the map), at an elevation of 8,300 feet, where it is seen extending for miles on either side in the form of cliffs. The outcrop is here about 100 feet

* Shakondhar of the map. The road from Kot to Deora is marked on the map.

thick. There is a second outcrop above it at an elevation of 8,800 feet, which extends (in thickness) up to 8,940 feet. I cannot say whether the bed extends from the outcrop at 8,300 feet up to 8,940 feet, as the intermediate space is well clothed with grass and the numerous blocks of gneiss on it may or may not be *in situ;* but I think the more probable explanation is that the bed has here thickened out to about 640 feet.

The gneiss was seen striking in the direction of the Bági road, but my path lay along the north side of the ridge at the head of the Kanati valley, at a high elevation, and I had to walk for some miles therefore before the gneiss cut across my path. I came on it again at an elevation of 9,300 feet (this is the elevation of the path—the crest of the ridge is higher), and from this point it formed, for a long distance, the crest and side of the ridge. The gneiss is here at times very granitic. My path left the gneiss at an elevation of 9,375 feet. I note here that the Hattu gneiss is simply an extension of this bed in the line of dip, which is very low. Owing to a bend in the line of strike caused by a change in the dip from east-11°-north to east-south-east, and finally to south-east-11°-east, the gneiss ceases to crop out along the ridge from this point; and the underlying mica-schists take its place along the crest of the ridge and form the picturesque rugged peak facing you at Bági. Where the path I followed struck into the road running north from Bági, the dip is 8° south-east-11°-east. Another bend in the direction of the strike brings down the gneiss again a mile or two further on. The elevation of the road at the outcrop is 9,300 feet. The mica-schists, just before the gneiss appears, owing to local crushing, dip north-east, east-north-east, and even north-west. The outcrop of the gneiss continues for 1½ or 2 miles, when the mica-schists re-appear, dipping east to east-south-east: 4 or 5 miles further on, the gneiss shows again on the road side, and continues for some distance, half a mile it may be.

These two outcrops demand a few words in detail. In the first of the two, on the Bági road, the gneiss has passed into an almost perfect granite of a finer grain, and even more advanced type than that of the Chor. It is only here and there, especially towards the northern side of the outcrop, that signs of foliation can be detected. When I first visited this peak, called by the natives Kot (it rises to a considerable elevation above the road, and is a very prominent object viewed from Hattu and other places round), I had not seen the outcrop described above. Kot looked very much like true granite, and I was at first tempted to suppose that its core had been protruded, in a more or less plastic state, through the mica-schists. These rocks were seen dipping easterly on both sides of the granite and fringing the granitic core below the road. At the top the granite seemed to overlap the schists. Having now visited this mountain three times, and carefully studied it each time, I am perfectly satisfied that it is simply an outcrop of the central gneiss in an advanced stage of metamorphism. Signs of foliation are, here and there, visible, it sends out no intrusive veins* into the neighbouring schists, and the latter are not altered at the point of contact with it. It is simply a bed of some 500 or 600 feet thick, the dip of which, for some distance, coincides with the slope of the hill, and the strike of which, for some distance, coincides with the direction of the ridge. The outcrop, 4 or 5 miles further on, is unmitigated gneiss. I have dwelt at some length on this outcrop, because I think its right interpretation will help us to explain the Chor.

The ridge running from Hattu past Bági to Kot must, I think, form the south-east slope of an anticlinal which has carried the central gneiss down to the Satlej. Proceeding from Kot to Hattu, the dip is south-east-11°-east, then south-south-east (probably quite local), and on the flank of Hattu east-11°-south. On the very crest of the ridge rising up from Bági to Hattu, there are rocks dipping north-east-11°-north to north. From Hattu down to Kotgarh the dip is unsteady, but seems to have a general north-easterly direction.

* I only observed one or two very thin veins *in* the gneiss.

At Kotgarh the general dip is low northerly, whilst at Kapu, the gneiss dips north-11°-west. These facts seem to indicate an anticlinal bend from the crest of the Hattu-Kot ridge down to the Satlej. If this is not the case, there must be a fault, for that the gneiss seen along the left bank of the Satlej, between Kapu and the Nogli River, is a continuation of the gneiss seen on the crest of the Hattu-Kot ridge, I see no reason to doubt.

VI.—SUNGRI—RAMPUR—SARHAN—SANGLA.

To get over the ground I must now be very brief and bald. From the outcrop of the gneiss 4 or 5 miles beyond Kot, there is nothing to record as far as Sungri. The rocks are micaceous and silicious schists. Elevation of Sungri 8,675 feet. Dip south-east. The Hindustan and Tibet road between this and Sarhan having fallen into decay, the road from Sungri plunges down into a very deep ravine, at the bottom of which the gneiss shows itself again. True dip about south-east. Beyond Dalog* the gneiss is again reached, and it continues for a long way. It gives place to mica-schists, but at Báli (Barl of the map), elevation 8,000 feet, the gneiss again crops out. Dip, eliminating local variations, south-east, all the way. The "central" gneiss continues to show down the descent to the Satlej as far as Kamsu. Dip, where road strikes Satlej, south-11°-west. From this point there is trap of the Mandi type for about 2 miles (the trap shows best in the bed of the river which I crossed and recrossed frequently on *massaks*). Schists resembling the Infra-Krol series show after this, and then the trap again. The strong quartz beds are burst asunder and twisted about by the trap in a wonderful manner. From Rampur (elevation 3,600 feet), the road rises to Gaora (8 miles, elevation 6,520 feet). Dip usually flat. Quartz-rock predominates for a long way; there are also micaceous and hornblendic schists. Near Gaora we have chloritic and talcose schists, and then gneiss, the foliæ of which are much crumpled. It only shows its small porphyritic crystals at right angles to the foliation.

To Sarhan, 11 miles, elevation of road 6,775 feet, the dip is rather low and north-11°-east most of the way, but veering round to north-north-west at Sarhan; rocks, mica-schists and gneiss, hornblendic, chloritic and talcose schists. Near Sarhan crumpled gneiss. The rocks are more than once repeated owing to the windings of the road in and out of the side valleys. This is a common feature in the sections exposed along the Satlej valley.

Sarhan to Taranda,† 14 miles; elevation of Taranda, 7,200 feet. Dip at first north-11°-west, afterwards north-north-west, with an occasional waver to north-west-11°-north. Near Taranda there are indications of great disturbance, the dip changes to north-north-west, then to west-south-west, then to west, then suddenly to south, with a high dip that soon becomes vertical. Then we come on three or four strong bands of hornblende-schists. Four miles beyond Sarhan the gneiss passes into a fine-grained whitish granite (only the gneiss altered) and then back into gneiss. From this point the "central" gneiss passes backwards and forwards from a porphyritic gneiss into a porphyritic and highly granitoid rock. Small dykes of the albite granite now become more and more frequent. Near Panuda there are beds of hornblende-schist turned up perpendicularly with the gneiss, which hard bye dips 37° to south-west. After this the dip was north-west-11°-north, north-11°-west, north-north-west, and finally settled down into north.

From Wangtu, owing to the complication arising from the frequent eruption of the granite, the gneiss runs into great masses of granitoid texture, and I could not make out the direction of the dip for many miles; where the bedding of the gneiss could be discovered, it dipped north-west-11°-west, further on, the dip appeared to be north-east-11°-north.

* Either Naora of the map or a village close to Naora.

† This is, I think, about a mile to the east of Nanaspar of the map, just to east of *Station*, 7,362 feet.

At Wangtu there is a bed of hornblende-schist which, I think, is an igneous rock in an advanced stage of metamorphism. It varies from 2 to 40 feet in thickness and traverses the granitoid gneiss, the bedding of which at Wangtu is obliterated. Sometimes two dykes run a parallel course, at varying distances from each other; at other times one dyke only is visible. It appears to be composed of hornblende and a triclinic felspar, and it shows distinct traces of a foliated structure. The manner in which it expands, or contracts, bifurcates and twists, seems only explicable on the supposition of its intrusion.

I was fortunate enough not to miss *the* minerals of the Satlej valley—beryl and kyanite: the latter I found in the central gneiss, and the former in a dyke of albite granite. What is noticeable about the beryl is that I found crystals piercing a patch of mica, a crystal imbedded in the felspar, and another in quartz, showing that it was the first crystal to become solid in the melted mass. Another specimen which I unfortunately broke was curved, which seems to indicate that the beryl crystals remained plastic for some time.

The trip up the right bank of the Satlej, which will take us to the scene of great granite intrusion, I leave for the present, and turn up the Baspa valley. I followed the right bank of the Satlej as far as Chagaon, crossing to the left bank below that village, and thence on to Kilba, elevation 6,525 feet. From Kilba to Barwa on the Baspa River (elevation 6,600 feet), dip steady north-east until three-fourths of a mile from the mouth of the Baspa, where there is change to 48° east. The gneiss through which I had passed all the way from Wangtu is now lost, and thin-bedded quartzite and mica-schists take its place. To Sangla (elevation 8,650 feet), the dip, at first east-south-east, afterwards varied to east-11°-north and east-11°-south. The angle, at one time as high as 45°, dropped rather suddenly at Sangla to 20°. At Sangla, blocks of the "central" gneiss indicate the neighbourhood of that rock. One end of the bridge rests on a block of gneiss 47′ × 41′ × 15′. The fall of the bed of the Baspu is 250 feet per mile.

VII.—Rupin Pass—Chansel Ridge—Pabar Valley.

From Sangla I ascended to Nuru,* and encamped on the snow at an elevation of 13,125 feet above the sea. It was at the very end of November. Shortly after leaving, Sangla, I came on the "central" gneiss. Dip east, and some crushing and contortion near Nuru. From Nuru to top of pass (elevation 15,480 feet, Gerard), dip low to east, then flat all the way down to Básuddár† (elevation 11,600 feet). Snow all the way, but rocks well seen in cliffs—they are mica-schists passing at times into gneissic beds. The latter, however, is not the central gneiss, or anything like it. Básuddár to Jako; elevation 8,950 feet. Dip flat all the way. Rocks mica-schist and silicious schists, getting more and more silicious as Jako is neared. Jako to Kuar (Pajearl‡ of map); elevation 7,640 feet. Mica-schists all the way. With some local variations, the dip is flat as far as Pandárgár (Gar = River). This is the Barabati of the map—a name I could not get any one to comprehend. After this the average dip is low to north-11°-east.

Near Kuar there is a compact weathered limestone with some carbonaceous rocks disintegrating into black earth. From Kuar down to the river (a considerable descent), and up to Dodra (elevation 8.300 feet) on the other side, the rocks are mica-schist closely resembling those of the Infra-Krol series. There are irregular strings of quartz in these schists (as in the Infra-Krol rocks), and the earth resulting from their disintegration is dark. Dip

* A halting place under the rocks about three miles on the north-east side of the pass.

† A halting place nearly under the Goras peak, or thereabouts.

‡ Properly Pujiári, so called because there is an idol temple there and a Pujári. Kuar is the collective name of three or four villages, and is the only name by which the place is known to people at a distance.

about west-north-west up to Kála Páni, a halting place in the forest at an elevation of 9,175 feet. Rock ordinary mica-schists. Dip moderate to north-north-west. I now crossed the Chansel peaks (elevation of pass 12,825 feet), and descended to Larot (Lorot of map), elevation 8,480 feet. Mica-schists all the way, gneissic at top of pass. At Larot (8,480 feet) the "central" gneiss is reached. Its course from this point is in a north-easterly direction down to the Pabar River, and then up again on the other side of the valley.

The elevation of Sangla, as before mentioned, is 8,650 feet. The gneiss cropped out, I should say, about 1,500 feet above it (I did not take the actual altitude). The elevation of the outcrop at Larot is 8,480 feet. There cannot be a difference in elevation of more than 2,000 feet between the two outcrops; and unless there are faults, of which I am ignorant, the central gneiss must pass right under the snowy peaks to the south of the Baspa River, and there must be fully 6,000 feet of mica-schists above the "central" gneiss.

Again, if the rocks between Kuar and Dodra are the Infra-Krol rocks, they, like the Infra-Krol rocks between Kapu and Rampur on the Satlej, closely overlie the gneiss, and rest, as I have suggested, on the denuded surface of the crystalline series.

From the gneiss in the valley of the Pabar, the dip rapidly flattened, and continued flat all the way to Chergao (Chárgáon), elevation 6,100 feet. The rocks are somewhat micaceous quartzites of a dark-grey neutral tint colour, in which the mica is very subordinate. From thence to Roru (elevation 5,250 feet), the dip, at first a very low to north-east, suddenly rose to 50° beyond Mandári, and then became perpendicular. The dip fell again rather suddenly to 35°, which lasted for some distance, and then gradually flattened to a very low north-east-11°-north dip. From Mandári the rocks are thin-bedded micaceous silicious schists. In the side ravines at Roru are some dark carbonaceous-looking schists brought down from the hills above. At Roru the dip is flat, and the thin-bedded mica-schists are often as straight and regular as the courses of bricks in a house. On the road to Sungri, with a few local exceptions, the dip is for some distance flat; afterwards the average dip is 25° east-south-east. Mica-schists all the way.

Proceeding in the opposite direction to Deora (capital of Jubal State), the dip is in general flat, though occasionally it is low to north-east and sometimes north. Now and then boulders of the "central" gneiss on the road side attest the presence of that rock in the hills above. Mica-schists all the way. I have also been from Roru up to the iron mines at Shiel, and thence down to Deora. Under Shiel I came on blocks of the "central" gneiss, but owing to grass and cultivation the gneiss did not crop out *in situ* on my actual path. I think there is probably a fault between the central gneiss of the upper Pabar valley and the gneiss to the west of Roru.

The gneiss, as previously described, crops out round the head of the Deora valley, and shows high up on the Kuper peak. I have also shown how a sudden change in the dip brings it out, on the opposite side, on the spur running out from the Kuper.Kánchu range in the direction of Chepál. On the Kuper-Kánchu spur, the outcrop extends from 9,620 feet to 8,000 feet. The nearest point on the Chor is Serai (Serán) (elevation 7,250 feet), and the outcrop of the granitoid gneiss there is on a level with, or a little above Serai. The distance, as the bird flies between the two points, is between 10 and 11 miles. The Chor gneiss answers well to the "central" gneiss in general characteristics. I feel satisfied myself that the granitoid gneiss of the Chor is simply an extension of the central gneiss beds I have been tracing out in this paper.

If this be so, does not this fact strengthen the view that the Krol, Infra-Krol, or Blaini rocks, between the outcrops of the central gneiss on the Chor and the Kuper-Kánchu range, rest on the denuded surface of the central gneiss series, and that the Chor and Kuper-Kanchu range were mountains standing up (far under the surface perhaps) of the Krol and Blaini seas?

If this view be correct, may we not suppose that the thickness of the Chor gneiss is not as great as it seems to be, but that it is, probably, simply an anticlinal in the gneiss, now masked by the metamorphism which has obliterated all traces of bedding.

In conclusion, I would venture to express the opinion that the metamorphism of the "central" gneiss is due to plutonic heat. The manner in which, as before described, the direction of the axes of felspar crystals changes, as the metamorphism increases, appears to me to indicate a freedom of motion which the constituent minerals could hardly have possessed unless the rock had been heated to a point approaching fusion. In the Satlej valley the signs of granitic intrusion into the central gneiss region are abundant, and they are not, I think, altogether wanting in the Chor. In the bed of the stream below Chaita (on the southern flank of the Chor), there is a huge block of the gneiss 67′ × 62′ × 37′. It is penetrated by granite veins which run at various angles; the principal one, about 4 feet wide, has caught up a fragment of the porphyritic granitoid gneiss in its passage, and this shows in the middle of the vein. This surely is an intrusive vein and not one due to segregation.

The presence of granite veins in the central gneiss of the Satlej valley and of the Chor seems to me to indicate that the central gneiss was at one time well within the action of the more deep-seated plutonic forces, and that its metamorphism is due to plutonic heat. If so, the Krol, the Infra-Krol, and the Blaini rocks cannot be older than the gneiss, and cannot really underlie it, whatever the appearances at certain points may be.

VIII.—Chini to Jángi.

My paper has already extended to such length that I must be brief in my remaining observations. Following the right bank of the Satlej, from Chagaon past Chini, the rocks all the way to Pángi are "central" gneiss alternating with schists of the mica-schist series. Near Chagaon there is a broad dyke of granite, and the signs of granitic eruption now become numerous. At Pángi the "central" gneiss is much twisted about by the rising granite, which high up in the cliffs overhanging Pángi is seen bursting through thin-bedded mica-schists. The mica-schists are much darkened by the passage of the granite.

Between Pángi and Rarang there is profuse granitic intrusion, and the rocks are riddled with granite veins in all direction. Beyond Pángi there is a broad dyke of whitish granite, and as it is neared the felspar in the gneiss is scattered about in its matrix in a most remarkable way. About ¾ of a mile on the Pángi side of Rarang, a dyke, 300 or 400 feet wide, cuts clean through the thin-bedded mica-schists up to the crest of the mountain, sending out large lateral dykes into the schists.

A little beyond Rarang the great eruption has taken place, and it extends from this point all the way to Jángi (8 miles by road—see the Trigonometrical Survey Sheet No. 65). The schists cling, here and there, to the face of the granite, and form subordinate spurs, round which the road at times winds; but the whole core of the mountain, extending from Rarang on the south-west sides of the Gongra peaks to Jángi on the north-east side of those peaks, is all granite. How far it extends in a north-westerly direction along the Gongra range I cannot say, but it evidently does not extend beyond Jángi along the Lipe road, as the natives told me the rocks in that direction were all *katcha* (friable).

I was not able to examine the left bank of the Satlej opposite Rarang, which I longed to do, but as far as I could judge by the eye, the granitic eruptions seemed to extend to the south, and I should not be surprised if the lofty Raldang peaks, which rise to the height of 21,250 feet and tower over the traveller within 6 miles of the road, were formed in whole, or in part, of this eruptive granite. That the great mass of granite between Rarang and Jángi is a truly eruptive rock I do not doubt. Between Rarang and Jángi I found numerous

blocks of mica-schist caught up by and buried in the granite. They are of all shapes, and varied in diameter from 2 inches to 2 feet. These blocks are identical in appearance and composition with the mica-schists through which the granite passes, and cannot, I apprehend, be due to segregative action.

IX.—MICROSCOPICAL CHARACTERS OF THE GNEISS.

In connection with the foregoing field observations, I have prepared many (over 220) thin slices of rocks for examination under the microscope. Latterly I have turned my attention to the central gneiss. Speaking generally, the internal structure of the rock—particularly when it passes into a granitoid state—is that which has usually been described as characteristic of an igneous rock.* The crystals of felspar and quartz contain within them micro-crystals pointing in all directions. Liquid cavities are often numerous, and they frequently contain bubbles that move about restlessly, similar to those described by Sorby and others.†

Sorby has shown in his paper on the microscopic structure of crystals (Vol. XIV, Q. J. G. S., p. 453) that those bubbles have been formed by the "contraction of the fluid on cooling." Air and gas bubbles are readily distinguished under the microscope from vacuum bubbles.

I note the presence of these fluid cavities and bubbles, because I wish to draw from this fact the inference that the central gneiss has been subjected to the influence of heat. This influence may, I think, be drawn from the cavities I have observed in these rocks. These cavities appear to have been filled with a mixture of steam or highly heated water, and air or gas, and the two substances have separated on cooling.

That the heat was very great, and reduced the rock to a plastic condition, may be inferred from the presence of what Sorby calls glass cavities. In these it is seen that the glass or mineral matter formed contraction-bubbles on cooling, similar to those in liquid cavities; only, in the case of glass cavities, the bubbles are never movable, there are often more than one of them in the same cavity, and they are not always spheres. Frequently, then, their shape conforms to that of the crystal or glass cavity in which they are contained.

Sorby remarks of glass and stone cavities: "Independent of the fact that in all essential characters they are identical with the crystals in artificial furnace slags, their very nature proves the igneous origin of the minerals containing them. This is especially the case with glass cavities, for nothing but igneous fusion could so liquefy the enclosed glass that perfectly spherical bubbles could be produced."

The presence of cracks in micro-crystals, where the cracks have not extended into the matrix, as occurs in several of my specimens, is also, I think, good evidence of the rock having been subjected to great heat. Subsequent to the cracking the pieces have been severed and floated to some little distance from each other. This proves that the matrix was in a limpid condition and flowed in between the fractured ends so as to leave no trace of the disturbance. All these cracks were, I apprehend, caused by unequal tension either on the cooling or re-heating of the mineral. In one case the fractured pieces (one of which contains a bubble) appear to have lost the sharpness of their outline by re-heating, whilst two pieces have been soldered together.

* I do not mean to imply by this either that the ock s an intrusive one that this structure cannot be produced otherwise than by dry heat. The fact noted mplies that, from whatever cause, the molecules had perfect freedom of motion.

† There is, unfortunately, neither time nor means to reproduce the excellent drawings of these objects sent by Colonel McMahon.—H. B. M.

Another curious class of crystals has been observed. At first sight they would seem to be illustrations of what Sorby calls stone cavities; that is to say, one mineral held in solution by another in a state of fusion and deposited on cooling. But as the dark opaque mineral is sometimes seen uninclosed by crystals and at other times is attached externally to crystals, I conclude that the dark minerals were first formed and the crystals were afterwards formed around them, or they were both floating about in a plastic state in the matrix and the dark minerals were absorbed into the white ones. I infer that the dark mineral was in a plastic state when the white mineral formed around it, or absorbed it into its own body, from the fact that where the dark mineral touches the outer sides of the white crystals, its surface generally conforms to the outline of the containing crystal as closely as if it had been deposited from a solution within the crystal itself. In one case when one of the dark minerals is seen riding astride on the back of a white crystal, it was observed that it had embraced the rounded form of the latter.

The study of the belonites contained in the felspar of the granitoid gneiss satisfies me that the central gneiss in its granitoid form was reduced to a plastic condition. Some of these belonites are very long, and occupy, in length, three or four fields of the microscope. Examples of belonites fractured and thrown out of their orignial position are not uncommon. Some can be distinctly traced to the physical strain of one belonite on another. These are not cases of irregularities of growth, but of distinct fracture after the formation of the belonites. A very striking instance (a most convincing one when actually seen under the microscope) occurs in which one of the fractured pieces is turned nearly at right angles to its original direction. The matrix must have been in a perfectly plastic condition to have allowed of this movement and to have flowed in round the fractured ends so as to leave no trace of the disturbance. I cannot believe that these fractures were simulated at the original formation of these crystals. I would as soon hold that the dip and contortion of strata are due to peculiarities in the original deposition of the beds.

The facts detailed in these observations show, I think, that the central gneiss has been subjected to great heat, and that where it passed into a granitoid condition, it became perfectly plastic.

In view of these results I think it would require strong evidence to justify the belief that the unaltered rocks of the Krol and Infra-Krol series underlie the crystalline rocks of the Central Himalayas.

The glass cavities, belonites, &c., described in these rocks, were seen under a magnifying power of 450 diameters.

REMARKS, EXPLANATORY AND CRITICAL, ON SOME STATEMENTS IN MR. WYNNE'S PAPER ON THE TERTIARIES OF THE NORTH-WEST PANJÁB IN RECORDS, VOL. X, PART 3, BY W. THEOBALD, *Geological Survey of India.*

In Mr. Wynne's interesting sketch of the tertiary rocks of the North-West Panjáb, there are a few points whereon I should like to make some remarks in correction, as I believe, of some of the views adopted.

Under the head "*Erratics*" (page 123 *l. c.*), Mr. Wynne enumerates numerous examples, regarding whose origin and character there can be little doubt, save with those who altogether decline to recognise the existence of glacial conditions in Northern India during recent times; but, in addition to these, my colleague describes others, which are not only, in my opinion, not 'erratics' at all, but belong to diverse geological epochs.

The erratics of the North-West Panjáb, properly so called, and to which I would restrict the term, are composed of the crystalline rocks and slates of various sorts forming the hills which stretch away to the north, or of other rocks, such as limestone, greenstone, &c. (but not granite), outcrops of which are known to occur in the adjoining region. More or less rounded, and not unfrequently sub-angular, blocks of these rocks of all sizes, from 1 to 50 or 80 feet in girth, are met with in the Potwár and the country to the north, some details respecting which I have given in the same number of the Records (page 140); but, in addition to these undoubted travelled blocks or 'erratics' properly so called, my colleague, Mr. Wynne, at page 124, alludes to "*smaller and less angular erratic blocks of red granite*" as being common south of Mt. Tilla and Rotás, and specifies one 7 feet in height and 19 feet in girth near the Collector's bungalow at the Mayo Salt Mines at Kewra.

Now, I quite agree with the supposition that "*these red crystalline boulders*" are derived from the "*cretaceous or olive group of the Eastern Salt Range,*" though not without a *caveat* as regards the large block at Kewra. This block rests on the salt marl, and though it may have been derived from the 'olive group' by the simple removal, by denudation, of the intervening shales and sandstones, it is, in my opinion, equally probable that it has weathered out *in situ* from the boulder bed which in so many places covers the 'purple sandstones' immediately overlying the salt marl and is itself covered by the '*obolus* beds.' Conglomerates, with red granite and purplish porpheries, from some unknown source, are found along the Salt Range from palæozoic times down to recent, and the only thing that favors the cretaceous age of the Kewra block is that, from its size, it owes its transport not improbably to ice, and the olive series has yielded proofs of glacial agency, which the older beds have not done as yet; but there is no connection between this possible 'erratic' of cretaceous age and the 'erratics' of the district proper. Both it and the similar boulders from the olive group are simply weathered out of beds in the neighbourhood, out of the outcrop of clays or conglomerates of palæozoic, mesozoic, kainozoic or recent age, and *are neither met with in the area wherein the true 'erratics' abound, nor do the northern erratics occur mixed with these within their own* (*i. e.*, red granite boulder) *area.* A sharp contrast exists between these red granite boulders and the '*erratics*' of the Punjáb, properly so called, both geologically, geographically, and physically.

The difference between my colleague and myself is one more of definition and terms than of fact; but it is one which I am not inclined to lose sight of.

Regarding my discovery of an ice-scratched boulder of red granite in the cretaceous group, Mr. Wynne's words require a little explanation: "One such boulder polished and striated apparently by glacial action was shown me by Mr. Theobald, who found it in *a wall* near Wahali, on the eastern plateau of the Salt Range, not far from where the conglomerate just mentioned is *in situ.*" The fact is that near Wahali the cretaceous boulder clay (much resembling the Talchir boulder bed in some respects) constitutes the sub-soil in some fields, and the boulders are simply gathered out of the field to clear it, and piled as a low wall along the roads, and in such a situation it was (virtually *in situ*) that my eye was attracted by the glitter of the *striated surface*, wetted by a passing shower.

An '*erratic*' this block doubtless was, *quoad* its original derivation and deposition in the 'olive' series, but it is not an '*erratic*' as regards existing conditions, or to be classed on the category of Potwár erratics.

Equally inapplicable, in my opinion, is the term '*erratic*' to the red granite blocks scattered about Tilla and Rotás. Their original source is, I believe, unknown, though they may have possibly come from the Arvali ranges. Their more proximate origin is from the denuded boulder clays of the cretaceous group in the Salt Range, or from still older beds such as I have already alluded to as covering the palæozoic "purple sandstone" of the Salt Range.

As regards, however, the so-called red granite erratics scattered over the country south of the Tilla ridge and Rotás, the *actual immediate source* is in the coarse upper Siwalik conglomerates which are there exposed, and in which both red granite and nummulitic limestone pebbles occur, as I have myself seen both north of the Bunhar River and also between it and the Chambal range.*

NOTE ON THE GENERA CHŒROMERYX AND RHAGATHERIUM BY R. LYDEKKER, B.A., *Geological Survey of India.*

At page 77 of the tenth volume of the Records I noticed a molar tooth which was brought from Sind, and which corresponds to the larger of certain specimens of teeth from Sylhet figured under the name of *Anthracotherium silistrense* in the second volume of the second series of the "Transactions of the Geological Society," and which figures are copied on plate LXVIII of the "Fauna Antiqua Sivalensis."

The teeth so named and figured were subsequently referred by M. Pomel to a new genus, *viz.*, *Chæromeryx;* he simply says at page 687 of the "Comptes Rendus" for 1848, *Chæromeryx* = *Anthracotherium silistrense:* the assumption here being that all the teeth called *A. silistrense* belonged to *Chæromeryx.*

On examining the tooth from Sind for the purpose of figuring it, I observed that it did not agree with M. Pomel's description of the molars of *Chæromeryx.* The Sind tooth has five columns, and is bunodont; now, M. Pomel, in speaking of *Chæromeryx*, says: "*Molaires supérieures à quatre mamelons seulement, au lieu de cinq.*" It is therefore clear that the Sind tooth cannot be *Chæromeryx.*

On again turning to the figures of the original specimens (F. A. S., plate LXVIII), I find that those in the Fauna Antiqua Sivalensis are more clear than the originals, and that they show that these teeth really belong to two distinct genera; the single large tooth (fig. 23) being bunodont and having five columns on the crown, and the smaller teeth (fig. 22) being selenodont and with only four columns. This difference appears to have escaped M. Pomel, who followed Pentland in referring all the specimens to one species.

The Sind tooth agrees with fig. 23, and belongs to the *Anthracotheridæ;* and seems to be nearest to the genus *Rhagatherium,* to which I am inclined to refer it. This specimen will be subsequently figured.

The smaller teeth, which alone belong to *Chæromeryx,* seem to me to be so close to *Merycopotamus* that I cannot but think they belong to a smaller species of that genus.

The changing of the genus of the Sind tooth does not of course interfere with the inference drawn as to the relation of the Sind and Sylhet deposits.

To the Sind tooth and of course the similar specimen figured in plate LXVIII, fig. 23, I propose to assign the specific name *Sindiense,* and for the present, at all events, to place it in the genus *Rhagatherium.*

The specific name *Silistrensis* will of course apply to the selenodont teeth from Sylhet, whether they be subsequently referred to *Chæromeryx* or *Merycopotamus.*

* From a private note from my colleague, Mr. Wynne, I gather that he never found these red granite boulders *in situ* in the conglomerates, whence he not unnaturally treated them as '*erratics*.' I was more fortunate, though not till after long and patient search. They are rare *in situ* when compared with the number scattered about, some being nearly 2 feet in diameter east of the Chambal range and south of Noupur (on the Bunhar River); *but then* they are very imperishable articles, and those scattered over the surface represent the waste of almost cubic miles of conglomerate!

Under these circumstances, therefore, I do not think these red granite boulders can be termed '*erratics*' unless we fall back on the hypothesis that all of these have been '*erratics*' during a former and wholly different phase of geological life to that which we at present have to describe and deal with.

DONATIONS TO THE MUSEUM.

(JULY TO SEPTEMBER 1877.)

Three flint knives found together with pottery, copper ornaments, and agate beads amongst ruins of ancient dwelling-places at Sutkágen Dor near Gwadur in Baluchistan.

E. MOCKLER, *Major,*
Political Agent, Gwadur,
(through W. T. BLANFORD, ESQ.)

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1877.

Titles of Books. *Donors.*

BERGHAUS, DR. H.—Karte der Alpen aus Mayr's Alpen—Atlas (1875), flsc., Gotha.

BROGGER, W. L.—Om Trondhjems stifts Geologi (1875), 8vo, Christiania.
THE AUTHOR.

ELLIOT, Sir H. M.—History of India, Vols. V—VII (1873—77), 8vo, London.
HOME DEPARTMENT.

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Part 3.] **1877.** **[August.**

NOTE ON THE TERTIARY ZONE AND UNDERLYING ROCKS IN THE NORTH-WEST PANJÁB, BY A. B. WYNNE, F.G.S., *Geological Survey, India.*

THE object of these notes is to give some account of the westward continuation of the tertiary band which forms the subject of Mr. Medlicott's paper on the Jamú Hills (Records, Vol. IX, p. 49), and is also referred to in Mr. Lydekker's paper on the Pir Panjál (same volume, p. 155).

Both of these papers deal with the tertiary rocks about the valley of the river Jhelum and to the south-eastward of that region, while I propose to consider those forming the Ráwalpindi plateau and stretching westward to the Afghán Frontier.*

* Besides the two special papers mentioned, there are several others, amongst which those included in the following condensed list are of more or less importance, each containing some information about the district:—

1.	Vicary	Upper Panjáb and Peshawar	Q. Jl. Geol. Soc. Lond., Vol. vii., p. 38.
2.	Fleming	Salt Range	Jl. As. S. Beng., Vols. xvii—xxii.
3.	Theobald	Ditto	Ditto do. do., Vol. xxiii, 1854.
4.	Ditto	*Chelonian* from Potwar	Records, Geol. Sur. Ind., Vol x, pt. 1.
5.	Falconer	Terty. fossils of E. Salt Range, &c.	Jl. As. S. Beng., Vol. xxiii, 1854.
6.	Murchison	Salt Range	Q. Jl. Geol. Soc. Lond., Vol. ix, p. 89.
7.	Verchere and de Verneuil	Himalaya and Afghan Mountains	Jl. As. S. Beng., Vols. xxxv and xxxvi.
8.	Lyman	Report on Panjáb Oil-lands	Public Works Dept.; Lahore, 1870.
9.	Waagen	Carboniferous Ammonites, Salt Range	Mem. Geol. Sur. Ind., Vol. ix, pt. 2.
10.	Ditto	Murree Hills	Records, Geol. Sur. Ind., Vol. v, pt. 1.
11.	Warth	Salt Range	Reports, Inld. Revenue, 1869 *et seq.*
12.	Waagen and Wynne	Sir Ban Mountain	Mem. Geol. Sur. Ind., Vol. ix, pt. 2.
13.	Lydekker	Tertiary *Mammalia*	Records, ditto ditto, Vol. ix, pts. 3 and 4.
14.	Ditto	*New Vertebrata (a)*	Ditto, ditto ditto, Vol. x, pt. 1.
15.	Ditto	Ditto	Pal. Indica, Vols. 1 & 2, Ser. x-2.
16.	Wynne	Upper Panjáb (b)	Q. Jl. Geol. Soc. Lond., Vol. xxx, p. 61.
17.	Ditto	Trans-Indus Salt Region (c)	Mem. Geol. Sur. Ind., Vol. xi, pt. 2.
18.	Ditto	Mt. Tilla, Salt Range	Records, ditto ditto, Vol. iii, pt. 4.
19.	Ditto	Pt. of Upper Panjáb	Ditto, ditto ditto, Vol. vi, pt. 3.
20.	Ditto	Murree	Ditto, ditto ditto, Vol. vii, pt. 2.
21.	Ditto	Kharián Hills	Ditto, ditto ditto, Vol. viii, p. 46.

(*a.*) In this paper a specimen of *Myliobatis* is said to have been sent by me from Kach: it is apparently from Katwár on the Salt Range, and was, I think, collected by Dr. Waagen.

(*b.*) Advantage may be taken of this opportunity to amend a few passages in this paper by knowledge since obtained: p. 62, the Siwaliks being miocene is now doubtful (Mr. Lydekker's papers, cit.). Table to face p. 63, last column:—the Tagling limestone is, according to Dr. Stoliczka, liassic; but in comparing the Sir Ban section with the Himalayan series it is placed as triassic, p. 64. The Púnch limestone has been since thought carboniferous, not Krol, p. 70. The conjecture as to there being hill-nummulitic beds near Uri in Kashmir was not supported by a subsequent observation, p. 74. In the section at Dandli, the beds *d3* have been found to overlie *c1* (Records, Vol. ix, p. 53).

(*c.*) Alterations necessary from subsequent information are mentioned in Mr. Medlicott's paper on Jamú.

I do not at present intend to pass beyond the subject of the tertiary zone further than to indicate briefly the rocks forming its supporting trough; and my notice of the newer formations will require less detail, because the rocks of the Salt Region beyond the Indus have been already described by me* as well as those of smaller areas in other parts of the district,† while a Memoir on the Geology of the Salt Range is in the press.

I must refer to Mr. Medlicott's paper, just now mentioned, for an account of the important changes affecting the tertiary zone on its passage from the country in which it was first examined by himself towards this district. Following out the geological features, he finds nearly every stratigraphical peculiarity of the Simla area vanish to the west. Though the upper and lower members of the great tertiary formation continue, the close identification of the intervening groups is still somewhat conjectural owing to the changes referred to.

The discovery that the whole zone was subject to such extensive modification as the total disappearance of marked unconformities, great boundary faults dying out by conversion into axes of contortion, or disappearing amid parallel stratification, was wanted to reconcile the earlier observations made in the Simla area with my own later ones in this district. The diversity of structure in the two regions will account for my having found it impossible to say which portions of the great conformable series in this part of the Panjáb represented each of the more clearly defined *discordant* groups of the Simla area; particularly as there is a prevalent general similarity throughout all the upper groups.

One of the local changes within the tertiary zone which may be analogous to the lateral variation affecting the whole formation as it passes westward, is the almost total absence of the very lowest beds of the sandstone series (as developed to the north) along the southern or Salt Range side of the trough. On the Himalayan side the uppermost nummulitic beds pass by alternation into the lowest part of the Murree group. On the Salt Range the junction is sharply defined, the parallelism of the stratification being the same in both cases.

Bordering this range there is a band in the sandstone series remarkable for the predominance of red clays, which, from its colour and nature, led me to suggest its being representative of the lower beds to the north. Below this zone, often close to the limestone, fossil exogenous timber is frequently found associated with reptilian remains. Similar petrified wood occurs in less quantity at a considerable distance upwards among the Murree beds on the northern side of the trough and Trans-Indus; but the red zone of the north, if present towards the Salt Range, is not sufficiently marked to be distinguishable. If this fossil wood can be relied upon to fix an horizon, it shows that a large part of the basal sandstone and clay series of the north side of the trough had died out in south and south-westerly directions.

In the Journal of the Geological Society of London,† I have discussed one of the most peculiar features of the country—the marked abnormal contact which forms the main northern boundary of the detrital tertiary rocks: it is not a single continuous fracture, but composed sometimes of several contiguous lines of displacement, amounting to more than ordinary faulting, inasmuch as it is generally attended by strong inversion of the outer rocks; and whether the ground it traverses be at an elevation of only one or of six thousand feet, nearly the same group of the upper nummulitic beds is always exposed along its southern side. On the other side of the line both nummulitic and Jurassic formations are in contact with these upper beds, which occasionally transgress its limits.

* See Nos. 17, &c., of list. † See No. 16 of list.

From its evident connexion with the Himalayan hills, I have attributed this abnormal contact to the out-thrust of the mountain mass on settlement, producing complicated inversion or oblique displacement. Although I do not think there is concealed unconformity present between the nummulitic groups on each side, I am not prepared to say there is absolutely none, nor can I venture to decide at what post-eocene period the dislocation took place.

The sub-division of the upper part of the great tertiary zone to the east has been carried out chiefly on the basis of slight lithological differences, or marked physical breaks, without collateral aid from the fauna so long known to exist abundantly in the newer beds. In this western district, these breaks being absent and fossil bones and teeth occurring also at lower stages than the usual horizon, the separation of groups has been still more tentative. It remains to be seen how far these divisions may be supported by palæontology, for the stratigraphical distribution of the fossils has not yet been fixed.

Amongst the lowest tertiary beds, the greater limestone groups of this district are conspicuous. The intervening band between these and the sandstones, &c., has been identified as Sabáthu (in part), but the upper members of the triple Sirmur group, peculiar to the middle Himalayan area, have their nearest equivalent in the "Murree beds," transitionally overlying the upper nummulitic rocks here. The higher portion of these Murree beds would also seem to occupy the place of the Nahan group, and they pass upwards into the Siwalik sub-divisions, continuous with those of the adjoining Jamú country.

The local characters of each of the four large nummulitic areas of this country present themselves strongly: the great limestone covering the Salt Range differs entirely from the even more largely developed nummulitic limestone of the outer Himalayan hills, and the upper transitional nummulitic group on that side of the basin shows both affinities and differences compared with the limestones beyond the Indus. These last are distinguished from all the rest by their close association with the great rock-salt deposits of that country and its overlying gypsum, a rock, however, frequently occurring in smaller masses among the upper nummulitic beds conterminous with the outer Himalayas.

The question has been raised whether the whole of the great nummulitic limestones of this country are not merely equivalents of parts of the Sabáthu zone of the Simla and Jamú areas.* I have concluded that these massive limestone groups occupy a lower place or places in the series than the variously-coloured and mixed calcareous and earthy (Sabáthu) deposits, for the following reasons:—These beds of limestone, clay, and sandstone (here recognised as Sabáthu) enter and leave the district as a more or less distinct band, external to the hill nummulitics, and passing into the overlying sandstone and clay series. These mixed beds, as an assemblage, differ from the mass of the limestones on the inner side of their boundary-fault or line of abnormal contact. That feature and the disturbed condition of the ground prevent the sequence from being seen, but towards the same side of the trough, in the Khaire Múrut ridge, I have found a section at a place called Chorgali clearly showing the whole of the local upper group resting conformably upon the more massive and clearer limestone of the older part of the series (see p. 118). Both groups being present in the same section, one cannot be the representative of the other.†

* Messrs. Medlicott and Lydekker's papers alluded to at commencement.

† Accepting Mr. Wynne's use of the term "Sabáthu," any argument in the matter would be needless, for it is perfectly evident that the coloured and mixed deposits west of Murree to which he restricts the word "Sabáthu" do overlie, and cannot represent, his hill limestone. But this name is one of our oldest Indian group-names: for many years the name "Subáthu" has stood to mean the nummulitic rocks of the outer Himalaya; and in its typical region, and very well marked through the Jamú hills, there is a bottom band of clear limestone under the coloured clays, and having, if possible, a higher claim to the name than they have. It has been reasonably suggested

The fault or contact-line, by its existence, proves the same thing: if there be displacement, the groups on each side cannot be exactly identical: if no displacement, there is no room for lateral transition; and if there should be unconformity, the groups must be even more distinct. The great limestones overlie, with conformity, actual in the Salt Range and apparent in the northern hills, cretaceous and Jurassic rocks, a relation in which the upper nummulitic beds are never found; on the contrary, these are united by intercalation with post-nummulitic rocks.

Notwithstanding, there are places in the other areas in which a certain resemblance to the upper nummulitic character is found. The Salt Region beyond the Indus is one of these, and at the eastern end of the Salt Range (near some typical "Murree beds") there are a few layers at the top of and above the nummulitic limestone which have an "upper" aspect.

Some of the local distinctions between the four nummulitic areas above mentioned coincide with marked variety in the *facies*, the size, or the abundance of their fossils. I am unable to state how far specific differences may exist, the collections not having undergone palæontological examination; but the impression of both vertical and horizontal distribution was gathered in the field. If this be the case, the conditions of one province may have invaded another, and thus blended the characters of deposits, generally contemporaneous no doubt, though perhaps not strictly synchronous one with another.

All the tertiary rocks under notice are, so far as is known, conformable and consecutive. The most distinct demarcations between the different groups occur:—at the top of the Salt Range nummulitic limestone where in contact with the Murree beds; and, between the upper and lower nummulitics, by reason of dislocation, at the northern side of the trough. Beyond the Indus the upper boundary of the limestone is frequently as distinct as in the Salt Range, but there are also obscure indications of transition by alternation upwards. All the other junctions are more transitional and indefinite. To such an extent is this the case, that it is impossible to say exactly where the change took place between the older marine and the newer fresh-water conditions.

Although stratigraphical conformity is obvious throughout the tertiary series, there are traces at several horizons of local breaks not otherwise apparent than by the presence of derived pebbles belonging to older portions of the same series, in some instances accompanied by small fragments of still earlier rocks. It is only at the upper limits of the Salt Range and Trans-Indus limestone that these derived nummulitic and other pebbles are coincident with the boundaries of any of the sub-divisions; they are elsewhere not limited to particular horizons.

A sketch map of the country herein referred to is annexed. It is on the same scale as that to accompany Mr. Medlicott's paper, and has the same colouring for the tertiary groups, the distinction now suggested of upper and lower nummulitics being also indicated. Both maps, joined at the meridian 74°, will convey a comprehensive view of the tertiary region of the Upper Panjáb.

PHYSICAL FORM OF THE GROUND.

The space referred to in this paper may be spoken of as lying between the Salt Range to the south and the outer Himalayan hills to the north, and extending from the river Jhelum

that this rock specifically represents the "Hill limestone;" and that its greater development to the west may have so taken place, that, partly at the expense of the upper deposits, the two would be in part representative of each other in the different regions. But this latter part of the conjecture is quite independent of the former, which scarcely admits of question: if the distinction of an upper and a lower nummulitic zone holds good, as is not unlikely, it will have to be carried out in the Jamú hills as well as in Hazára.—H. B. M.

westward across the Indus to the Kohát frontier. It includes the whole of the Ráwalpindi plateau, or "the Potwár," a name strictly belonging to an eastern portion of the plateau, but sometimes used even by natives of the country in a more comprehensive sense.

This ground, having an area of about 7,000 square miles, forms an undulating expanse edged by the northern slopes of the Salt Range, and lies about 1,000 feet higher than the alluvial plains and desert south of that range. It appears analogous to the Dúns of the Southern Himalaya, and is in reality one of the most strangely broken tracts I have seen, intersected by numberless deep, ramifying ravines called "*khadera*," the rapid extension of which is attested by the isolated remnants of the neighbouring "*maidán*" (or plain) included amongst them. The heads of all the streams not in the hills issue from such a fretwork; and along the larger water-courses, though wide flats of auriferous sand and quicksand form their lower levels, ordinary alluvial border tracts are rare.

From this plain or plateau rise a few reefs of bare rock, often only narrow, jagged, vertical walls, and one more considerable mural ridge called "Khaire Múrut" (over twenty-two miles long and reaching to 1,500 feet above the adjacent country) runs west-by-south from the neighbourhood of Ráwalpindi.

The Murree hills, twelve to twenty-eight miles distant from the same station in an opposite direction, culminate in heights of over six, seven, and eight thousand feet, declining in successive nearly parallel ridges towards the direction of Jhelum cantonment. They have a general south-west north-east trend, which is also that of most of their numerous, sometimes sinuous, axes of contorted stratification, the folds being most compressed northwards. All the ridges are united by a zigzag subordinate backbone, forming the Cols, and rudely conforming to the adjacent course of the Jhelum.

Ridges at their eastern ends parallel with these, then bending more to the west, form high mountains immediately north of the Murree hills. Towards the plateau they decline; and the Grand Trunk Road passes through gaps near their western termination at the Márgala Pass. Beyond these again rise the Hazára hills, and the fine range of Gandgarh partly bordering the Upper Indus.

From the Márgala pass two ranges run westward south of Attock; gaining in elevation they unite to form the lofty Affrídi hills overhanging Kohát; then passing south of the Peshawar valley they culminate in the Khybur mountains and Sufééd Koh of Afghánistán. The most southerly of these, called the Chita Pahár, edges the Ráwalpindi plateau on the north.

In the Kohát district the part of the ground under notice presents a series of long ridges, closely clustered, running more or less east and west, often crooked and of varying but not insignificant height. Viewed from the plateau, they assume the appearance of a connected range. The valleys between these are for the most part rugged; but some flat cultivable patches enhance the sterility of their generally treeless surroundings. A few high summits occur near the Indus, and the whole cluster lies between the Afghán hills and the Shíngarh chains to the south.

The Salt Range which edges the Ráwalpindi plateau southwards and is sinuously prolonged Trans-Indus, in both places presents wild and mostly unfertile tracts. Cis-Indus it forms a precipitous escarpment overlooking the "Thal" (or desert) and lower plains. Further west, with numerous disturbances and dislocations, the northern inclinations of its strata rise to steeper angles, and the stronger beds support a mass of tertiary rocks, whose deeply serrated outline, Trans-Indus, and the silvery sheen of its bare sandstone summits, betray the presence of the upper tertiary series, making the Pushtu name *Shíngarh* as suggestive in its half English sound as in its vernacular meaning of "Grey mountains." The

northward extension of these rocks, however, in the direction of the dip is interrupted by faulting; most of the lower ground and hills towards Kohát being occupied by older parts of the series.

Drainage.—Crossing this whole tract of tertiary rocks, the Jhelum river is a racing, rapid torrent, hemmed in by mountains; the Indus (or Abba Sín), larger and more powerful, flows from among lofty and picturesque ranges, across an expanding and highly cultivated plain, till it receives the Lúnda or Kábul river at Attock. It then cuts its way through every one of three intervening ranges, and has formed for itself a deep narrow gulch through the rocks of the plateau, running swiftly, with occasional rapids, until it reaches and escapes into the lower plains at Kálabágh. The minor drainage of the district mainly seeks the Indus, some smaller portion reaching the Jhelum. It is everywhere distinguished by its cross-country character, preferring, in many cases, to intersect the hilly or mountainous ranges rather than to follow the larger depressions of the surface. Even the Soán, the most considerable local stream, rises in the hills at Murree, not very far from the Jhelum, yet wanders away westwards to the Indus, by a part of the plateau-land which itself sends affluents to the Jhelum river through ridges of the Salt Range. The Haró, too, in the Hazára valley to the north, does not take all that drainage to the Indus, for the Dore, which would otherwise form one of its upper tributaries, turns aside, crosses through part of the lofty Gandgarh range, and finds thus a shorter way to join the great river at Turbela. The Tíri (Teeree) Towey, another tributary of the Indus, from the Kohát district, changes its course from one depression to another, intersecting the ridge between.

These peculiarities of the drainage tend to show that its course was initiated more directly by agencies of elevation than by the results of atmospheric denudation acting, at different rates, upon rocks of varying texture. The valleys of the ground are not always those of the rivers; both are now valleys of denudation, but the directions of the streams were decided by much older contours of the surface than now exist. The rivers have maintained their courses, even though the wasting agencies in carving out prominent features have at the same time lowered the "divides," in some localities to hardly noticeable undulations.

The antiquity of the courses of the larger rivers Jhelum, Indus, and Kurram is proved by the Himalayan transported detritus, brought to form late tertiary (Siwalik) boulder beds and conglomerates, being thickest near their banks.* A later phase in their history is marked by the occurrence of the same hard detrital and stream-worn blocks lying upon the adjacent mountains at heights of about 2,000 feet above the present bed of the Indus;† and a still later period of the river action is indicated by the same pebbles and boulders interstratified with the superficial deposits of the country along this river. Such hard boulders now form its bed at Attock, and are doubtless still travelling downwards from the Himalayan regions.

CLASSIFICATION.

The rocks found in the district may be classified as follows:—

	Natural order.
POST-TERTIARY— *Unconformity.*	Conglomerates, pebble beds, silt and alluvium.
UPPER SIWALIK—Pliocene (Lydekker),‡ about 4,000 feet.	Brown, drab, and reddish clays, mammalian and reptilian remains. Soft grey sandstones, conglomerates, and orange or grey clays. Mammalian remains, &c., not abundant.

* This feature was pointed out for the Mid-Himalayan rivers long since by Mr. Medlicott.

† Over Kálabágh, and again on the Chita Pahár (Mountain) near their highest elevations above Bág and Choi.

‡ Records, Geol. Surv. Ind., Vol. IX, p. 87.

LOWER (RED AND GREY)[1] SIWALIK—Pliocene (Lydekker), about 10,000 feet.		Soft grey sandstones and brown or grey clays, slightly harder grey sandstones, many red clays; mammalian remains, bones, teeth, &c., locally abundant. Ossiferous throughout.
MURREE BEDS—Upper Miocene (Lydekker), 7,500 feet average.		Harder grey sandstones, with soft zones, red or purple clay. Fossils—reptilian and other bones not numerous, some fossil wood. At Salt Range, purple and grey harder sandstones, red and purple clays, a few green sandstones (locally); reptilian remains, exogenous wood, bones scarce, and fragmentary teeth rare.
NUMMULITIC—Eocene to Miocene (Lydekker).	Upper 800 feet average.	Greenish-grey and purple sandstones, grey, olive-brownish, red and variegated clays with masses of rock gypsum. *Foraminifera*, (*nummulites*, &c.), *Gastropoda*, Bivalves, fossil mammalian bones occasionally. Crustaceans rare.
Trans.-Indus 1,700; Salt Range 500; Himalayan 3,000 — Average 1,066	Lower ...	In Salt Range, Trans-Indus, and part of Chita Pahár. Whitish or usually pale limestones, coaly shales, &c., below. In Kohát district are sandy limestones, olive shales, and red clays also, as well as gypsum and rock salt. Fossils, *Foraminifera* (*Alveolina* locally numerous), large *Gastropoda*, Bivalves, Echinoderms, &c. Northern or hill nummulitic, grey limestone weathering pale, dark fœtid limestones, olive shales: *Foraminifera*.

Obs.—Series parallel and conformable from the pale limestones upward to top of Siwaliks. The boundaries of the groups are transitional and indefinite.

The downward continuation of the series, so far as now known, includes the following formations:—

Southern or Salt Range series.

Cretaceous (?)	... Sandstones, conglomeratic clays, shales.
Jurassic	... Sandstones, limestones, oolite, &c.
Triassic	... Limestones, shales, red sandstone and clays.
Carboniferous	... Limestone, sandstone, shale.
Speckled sandstone	... Sandstones, clays, conglomerate.
Magnesian sandstone	... Dolomite, pseudo-limestone, shale, sandstone.
Obolus beds (Silurian)	... Dark, clunchy, shaly and sandy beds.
Lower or purple sandstones ...	... Purple sandstone, replaced by conglomerate.
Gypseous series	... Scarlet marl, gypsum, rock-salt.

N. B.—The series differs at either end of the range by absence of, or changes in, certain groups.

Northern or Himalayan series.

Cretaceous	... Limestones, some rusty and sandy.
Jurassic	... Limestones, sandstones, black (Spíti) shales.
Triassic	... Limestones, magnesian in part, shales, sandstones.
Infra-triassic	... Silicious and dolomitic breccia, shales, sandstones.
Silurian (?) Attock slates (azoic) ...	... Black and grey slates chiefly, limestones, magnesian in part, trap.
Metamorphic	... Part of the Attock slates usually slightly altered.
Crystalline	... Syenite-gneiss, trap rocks, and granitoid rocks.

N. B.—Carboniferous rocks are unknown in the northern series of this district, but occur in Kashmir and to the east of the Jhelum (see Mr. Lydekker's paper on Pir Panjál).

In describing the rocks belonging to the different tertiary groups, I shall follow what is known or appears to be their chronological order, commencing with the earliest.

NUMMULITIC LIMESTONES.

Hill Nummulitic beds.—Of the four local kinds of nummulitic limestone the oldest perhaps is that of the outer Himalayan hill region: its position and general aspect, with its less fossiliferous character and the manner of its association with the mixed groups, are points giving sufficient grounds for a strong inference that this is the case. It is, generally speaking, dark-coloured, fœtid and massive, with nodular or lumpy bands, the whole irregularly and locally interstratified with masses of brownish, olive or darker shales.

Strong zones of paler grey splintery limestone also occur, and towards what appears to be the upper part of the group, the limestone, though still darkish, weathers of a lighter bluish-grey colour. Stratification is sometimes most plainly seen, sometimes nearly impossible to detect, and disturbance, compression and dislocation have left the succession obscure.

Those beds overlying the next older rocks are either unfossiliferous or only contain black specks that may have been organic, with occasionally minute sections of discoid foraminiferous organisms, having a single tier of cells arranged as a helix; or else cross-sections of another minute form less than semi-circular, with an obtuse angle midway opposite to the curved side, subtended by three or four concentric chambers equally divided by a closely set group of radial septa. I have only found this form in the lowest beds, and have not been able to get it determined. In the shales much higher up in the group are sometimes clumps of very small clustered and branched corals with occasionally numerous little *Foraminiferæ* (similar to the discoid form just mentioned) referred conjecturally by Dr. Waagen to *Rotalinæ*.

Many of the limestones enclose nummulites, whose sections are generally small in size, varying from that of the longest to the shortest diameters of grains of rice or wheat. The whole assemblage of organisms in these hill-beds is distinguished by scarcity and minuteness as compared with the other nummulitic rocks.

Westward, the darkest-coloured limestones are less common, the shales thinner and not so frequent. Strong grey limestone, weathering lighter, occurs along the Chíta range; still the dark shaly variety, with lumpy bands and a few layers crowded with small oysters, appears in the more central, northerly, and western parts of the range, also in the Niláb Gash mountains beyond the Indus. Yellow ferruginous, magnesian-looking bands are occasionally present, and there are black alum-shales in one or two places at the base of the series which may be of an older formation. At one place (Choi), apparently much higher in the group, is a lenticular pocket of bright coal and coaly shales, amongst the ordinary dark limestones and brown shales. Thin carbonaceous shale also occurs locally between these limestones and the Jurassic beds at Chamba Peak north of Murree, but are not constant in that position.

North of Niláb-Gash, at Pullosi Pass, grey limestone contains casts of large *Lucinidæ* similar to those of the Salt Range; and near Shaladetta I found, loose, one of the great Gastropod casts (*Cerithium ?*) peculiar to the Salt Range limestone. These indications are, however, too slight to establish any close identification of the northern limestone group with that to the south. They are lithologically different accumulations, although they appear to be generally contemporaneous as upper and lower parts of the same formation.

The Khaire Múrut ridge is a mass of solid, contorted, grey nummulitic limestone (of the same kind as that found in the eastern part of the Chíta Pahár opposite), flanked by the upper nummulitic group faulted, overthrown and concealed by talus deposits, yet well exposed where it forms the western and lower extension of the ridge. The stronger limestone, and indeed the whole ridge, appears to have had an anticlinal structure greatly modified by compression and faulting. At the eastern end in the lower ground are some indications of the conformable succession of the newer nummulitic group to the hill limestone, and again westward at Chorgali* I found the succession and conformity of the two groups distinctly displayed. (The section will be noticed when writing of this newer zone.)

Under the conditions of disturbance and dislocation it is hard to conjecture what may be the correct thickness of these hill limestones and shales. An attempted estimate carefully

* A pass infested by robbers in the Sikh times.

taken from one of the most detailed sections I have got near Murree* shows thicknesses for parts of the formation of over 2,150 and 2,700 feet; this is, however, but a partial result, and the whole may much exceed 3,000 feet. There is a large group of light-coloured evenly bedded limestones in the Hazára hills which appears intermediate between the hill nummulites and the cretaceous rocks.

Salt Range Nummulitic Limestone.—In this region the formation is made up almost entirely of limestones presenting a greater unity of character and uniformly a much paler colour than the northern group. Intervening clay or shales are rare or absent, and where any occur, they partake of the light colour of the limestone. Nodular or lumpy beds, made up of solid portions surrounded by a softer coating, are not uncommon; compact and cherty limestones often predominate in the upper portion. Many of the beds are highly fossiliferous, containing numerous imperfect casts of large Gastropods more than 8 inches in height, or large Bivalves, and also Echinoderms frequently as large as small melons. One small fossil, *Ostrea Flemingi*, seems exceptionally well preserved. *Nummulites* are numerous, and *Alveolinæ* also occur, as well as other *Foraminiferæ*.

In the Eastern Salt Range layers of pale purple and yellowish limestone conglomerate, with limestone and flint nodules and pebbles, the matrix charged with small *Nummulites*, have been found to form the very uppermost few beds, conformably overlaid by the sandstone and clay series. In the somewhat outlying Diljaba and Bakrála ridge these beds re-appear at Goragali, but separated from the limestone by a mass of greenish shales several feet in thickness, and having much the appearance of the upper nummulitic beds on the north side of the tertiary belt. Some red flakey clay or shale is also associated.

At the base of the Salt Range nummulitic formation dark shales are very commonly present, frequently overlying white, sub-conglomeratic, coarse and fine sandstones interstratified with pale red sandstone bands and red or lighter grey (rarely gypseous) shales.† The dark shales are often coaly or contain a single or divided layer of bright coal averaging three feet (the Salt Range coal). Mottled red and white unctuous or lateritic clay occurs as an accessory in thin or thicker beds. These lateritic and hæmatitic layers sometimes occur at the very base of the limestone, and sometimes below the coaly shale or among the white sandstones. They vary a good deal as to the amount of iron present, are sometimes pisolitic (when the grains are used as shot or bullets) or replaced by white clay, and they are sometimes altogether absent.

The coaly shales are not the very lowest nummulitic layers. At places in the East Salt Range, where most carbonaceous, one or two underlying calcareous beds contain nummulitic fossils; and to the west, as in the Bakk ravine (Músakhel), a considerable thickness of nummulitic limestone separates them from the lower formations. This variegated and mixed band below the main limestone has in the eastern region a probable thickness in some places of more than 200 feet, but parts are often concealed by talus deposits. It is less prominent to the west.

The whole southern nummulitic group frequently shows itself in high cliffs and varies in thickness from about 500 feet to nothing, being entirely absent in places at either extremity of the range Cis-Indus.

* The observations for this section were mapped on a scale of 300 feet to an inch and carried along the clear cuttings for the new road between Murree and Abbotabad for over 23 miles. I look upon its information, as far as it goes, as reliable.

† At one place south of Chel hill, East Salt Range, a layer in such shales not far below the limestone contains narrow, pointed leaves.

Upon the evidence of the arenaceous, argillaceous, and rarely gypseous layers below this Salt Range limestone,* or the small local development of layers with an upper character at top, I can scarcely venture to assert that the whole group is the counterpart of the upper nummulitic beds of this district or elsewhere; still I think there may be sufficient reason to suppose that similar conditions recurred at intervals, and that this Salt Range series may at least be, generally speaking, newer than the greater part of the northern hill nummulitic limestones.†

Nummulitic Limestones, &c., beyond the Indus.—I have so lately described these rocks, (in Vol. XI of our Memoirs,) where as yet I am best acquainted with them, that a short notice will suffice. The most striking and constant band is one of hard grey and often variously tinted pale compact limestone 60 to 100 feet in thickness. This in colour and texture has some resemblance to bands in the Salt Range: it contains *Nummulites* and *Alveolinæ*. Below it are other grey lumpy and sometimes cherty limestones, with various nummulitic fossils; some peculiar to this region, and none possessing the great size of some Salt Range forms.

Underneath these limestones there is a zone of deep red clay, having subordinate sandstone and hæmatitic layers; it varies from 1,500 to 400 feet in thickness, and in places contains small fragments of fossil bones. Locally this clay gives place to olive sandstones partly conglomeratic; greenish clays and impure limestones with *Alveolinæ* and *Nummulites*. This mixed group reaches a thickness of 100 to 350 feet. Below all are the alum shales, the massive layers of gypsum, gypseous clays, and the enormous accummulation of rock-salt, often distinctly and regularly stratified. In the upper part of the series there are appearances of alternation with some of the overlying purplish sandstones, &c., but the folding and inversion of the rocks is so intense over the district that appearances cannot be always trusted.

The united thickness of the Trans-Indus nummulitic rocks, including 700 or 800 feet for the rock-salt and 300 for the gypsum, is estimated at from 1,600 to 1,700 feet, and may be more.

There are points of resemblance between this series and that of the Salt Range, but also many differences. Where the limestones are thick, pale, and fossiliferous, the resemblance is strongest; and junctions between the limestone and overlying sandstones, though often *locally* resembling the sharpness and definition of the same in the Salt Range, have here and there more similarity to the transitional nature of the newest beds of the whole nummulitic formation. The Trans-Indus nummulitic area has therefore general characters intermediate between those of the Salt Range and upper nummulitic groups, and is most nearly allied to the last.

The Upper Nummulitic group of this country, coming from the eastward, appears first in the Murree hills, then passes westward, edging the outer Himalayan region, crosses the Indus at Báhtar, continues close along the south side of the Niláb Gash mountain, and leaves the district as a continuous zone to enter the Jawaki Affrídi hills. A spur from these hills to Dandi on the Indus has beds upon its flanks which may belong to the group: it re-appears, at Khaire Múrut ridge, deeply faulted into the *khuds* and mountains of the Hazára district north of Murree, and similarly placed in the Mírkulán pass south of the Peshawar valley.

* The coaly shales afford no point of comparison, no similar zone occurring in the upper nummulitics of this district, nor any band that could be safely referred to the same horizon among the northern hill limestones.

† The East Salt Range nummulitic group presents a most striking resemblance to the bottom beds of the nummulitic series throughout the Jamú hills.—H. B. M

The rocks consist of greenish drab, grey, red, and deep purple clays or shales, associated with masses of gypsum and alternating with thin layers of buff, grey, or bluish limestone frequently of lithographic texture, sometimes whitish and marly. Among the calcareous beds many are little else than aggregations of *Nummulites*, *Operculinæ*, &c., but sometimes their matrix is a dark green or yellowish or reddish sandstone, and sometimes greenish clay or shale. Beds entirely composed of small Bivalve casts or of *Turritellæ* occur, but more rarely, and with the former, fragments of small Crustaceans have been once observed. The marine fossils are greatly more numerous individually in these upper beds than in any other nummulitic rocks of the country. Large mammalian bones or smaller fragments have been also found in this group, occasionally with *Nummulites* attached.

The group varies as to predominance of any of its ingredients; sometimes limestones and sometimes clays are most developed below; and in places there are but few calcareous layers present. Strong zones of yellowish grey sandstone appear in westerly localities, while eastwards a great thickness of bluish grey sandstones and purple clays resembling those of the overlying series are included. These are without fossils, except fucoidal impressions.

One remarkable but thin contact layer occurs here and there where the main group of limestone beds is overlaid by sandstones. It consists of a nodular and conglomeratic limestone, passing into calcareous sandstone, and containing concentric concretions with subangular lumps or pebbles of fossiliferous nummulitic limestone. Strings, layers, and groups of *Nummulites* occur also in the paste. Subject to variation as to its conglomeratic aspect, it has been found at different places in this northern band, also along the Salt Range and Trans-Indus, with one exception always marking the junction between limestone and sandstone stages. This exception is where a limestone band made up of small concretions weathering detached (otherwise a junction or representative layer)* was found interstratified with Murree beds, north of the Dúga stream, between Mári and Jand. The layer has some importance, tending to unite the groups last described with this, if it can be taken to mark an horizon, but appears to occur accidentally (like other nummulitic layers among the lower Murree beds) in the exceptional case noticed.

The character of transition and unity with the overlying Murree beds is marked along the place of junction by alternations of rocks which might belong to either group. Sandstones and clays like those overlying are common, and limestone layers occur considerably removed from any other upper nummulitic rocks. Beyond the Indus such appearances are more frequent. Towards the Murree hills, limestone bands, very similar to that of the adjoining mountains, are associated with these upper nummulitic rocks: the disturbance is, however, so great, that it is not clear whether they are sometimes intercalated or introduced by faulting. In some cases, though dislocated, they appear to belong to this group, in others to be separated by faulted portions of it from the remainder of the hill beds.

Disturbance also obscures any very satisfactory estimate of the thickness of the group. From contorted sections in the lower ground this was found to measure more than 1,500 feet. Mr. Lyman gives 500 feet for the more calcareous part of Fatahjang, and after deducting probable repetitions in the Kúldana section (where the great bulk is made up of beds similar to the Murree sandstones, &c.), there would remain, according to that exposure, 6,525 feet. The rocks occupy a space more than a mile in width across the strike, including, among the furthest from the hill nummulitic beds, a strong zone of limestone of 750 feet, apparently displaced. It is difficult to believe in this great thickness, but I have tried to restore the section, so as to unite the strong outer limestone with that of the hills, by means of supposed

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* See Trans-Indus Memoir, pp. 105, 118, 151.

faults, without success or probability; unless the 750 feet of limestone and some adjacent undoubtedly upper beds may have once formed part of an anticlinal curve, all trace of which is now lost.* Independently of this doubtful section, the group may be taken as including from 500 to 1,500 feet of rocks.

The place of the whole upper beds as newer than the more solid and massive limestones occupying a central position in the district, is fixed by the following section found at Chorgali (Khaire Múrut ridge) southwards from Fatahjang: thickness about 400 feet; inclination generally high to the north and turning over southwards:—

LOWER, TRANSITIONAL PART OF MURREE BEDS ...	Purple, grey, and greenish sandstones and pseudo-conglomeratic concretionary beds; clays, if present, concealed; rocks locally crushed in places.
UPPER NUMMULITIC ...	Hard whitish sandstone, including a mass of nodular limestone. Pseudo-conglomeratic, calcareous, concretionary "junction-layer" with concentric concretions and subangular lumps; nummulitic limestone; strings, layers, and groups of *Nummulites* in the paste. Lumpy limestone with purple and dark shaly partings. White splintery shales. Strong lumpy limestone. Mass of pale greenish shale, with two beds of earthy limestone; whitish hard, marly limestone, alternating with a few lumpy layers below; conforming to an arch of,—
LOWER NUMMULITIC ...	Hard lavender-grey nummulitic limestone of the same kind as forms the nearest part of the Chita Pahár range and the mass of the Múrut ridge.

The massive gypsum, red clays, and most highly fossiliferous beds are wanting here. This, together with the scanty representatives of the group in the few uppermost layers of the Salt Range much further southwards, may indicate a gradual disappearance of the zone in that direction, or even by lateral transition, it being represented in the upper portion of the Salt Range limestones.

It is in this upper group that the principal petroleum springs of the country (such as they are) are situated. The mineral oil does not appear to be confined to any particular horizon or even to the group, being found among limestones nearly in the middle of the Chíta range, in the nummulitic beds beyond the Indus and impregnating the salt in places. It occurs just below the junction of the limestone with the overlying sandstones at Jaba in the Western Salt Range, and there are traces of it in the sandstones of the Murree group near the Múrut ridge. Sulphur springs often occur in association with the oil.

Murree Group.—In this great transition group the passage has probably taken place from the nummulitic marine conditions to those of the fresh-water series above. Among its very lowest layers, which are inseparable from the underlying group, I found a bed close upon the limestone, containing thick, strongly ribbed shell-casts of marine aspect (a *Cardium ?*), associated with numerous and large crocodilian remains (see Trans-Indus Memoir, pp. 130, 135). In detail these rocks include harder sandstones than occur higher in the series, often of pale grey or purplish colour below, and crowded with obscure plant-impressions resembling Fucoids associated with Annelidan markings. Such beds are not unfrequently ripple-marked.

A strong purple colour pervades the whole lower portion of the group, which shows an endless alternation of red and purple clays, with purple and greyer thick or thin sandstones and concretionary earthy or slightly calcareous bands. In upper portions and among southern representatives of these Murree beds, pale, soft, grey or greenish sandstone zones are intercalated with the more usual purplish clays and sandstones. To the southward, also, and more

* For further details of this section, see Records, Vol. VII, Pt. 2.

rarely elsewhere, conglomerate or pebbly beds are found containing rounded fragments of nummulitic limestone, sometimes with hard pebbles from still older rocks. These are pretty often seen in the ground about the eastern extremity of the Salt Range.

Other fossils are not numerous in the Murree beds, yet scattered bone fragments, crocodilian teeth, or scutes and pieces of exogenous fossil timber may be found near its southern base. These remains are locally numerous on Mount Tilla, along the Salt Range and beyond the Indus. Bones occur immediately over and partly in the upper surface of the nummulitic limestone at a pass on the road to Kohát from Kushálgarh near Gúrgúrlot mountain; again in the lowest sandstones at the northern end of the Chicháli pass in the Shín Garh mountains; occasionally in the neighbourhood of Fatahjang, and rarely at the foot of the Murree hills. In many cases they are too fragmentary for identification; some large specimens, however, of mammalian bones appear among these rocks on the Bakrála ridge near Domóli. In the same range, over Bakrála pass, and also near Zyarut, west from Jand towards the Indus, I found fragments of the teeth of *Mastodon;* but the best fossils of the group are those recorded by Mr. Lydekker (Records, Vol. IX, pt. 3, & Pal. Ind. cit.) from Kushálgarh, found at some now unknown locality, and including *Mastodon, Dinotherium, Listriodon, Rhinoceros, Antoletherium, Sus,* and *Amphicyon.**

Intense disturbance, and along its northern limits inversion, greatly obscure the thickness of this group, which must be nevertheless very large. The whole of the nearer hills south of Murree and the Murree ridge itself are formed of its beds; one steeply inverted portion at that station some 2,600 feet in thickness forming but a small portion of the ridge. In the lower ground there are appearances of nearly vertical beds for miles across the strike, but these are most probably produced by compressed folds, the upper parts of which have been denuded, for in the general strike towards the Indus the rocks are seen to be closely contorted. The beds occupy a width of from ten to sixteen miles across the northern side of this district; beyond the Indus they appear thinner, yet still form a prominent purplish belt round each of the disturbed nummulitic anticlinals of that country, and along the Salt Range they have certainly lost thickness as well as much of their characteristic aspect. On the whole, 5,000 to 8,000 feet may not be too large an estimate for the group.

The newer tertiary rocks being all transitional, it is as difficult to fix a definite upper boundary for these Murree beds as to separate them from the rocks below, yet the brighter colours of the clays and sandstones upwards are sufficient to indicate some difference and an approach to the newer groups. The marine nummulitic conditions were no longer present, and there is no certain trace of the land surface on which the timber grew which is found fossilised in these Murree rocks, for all the specimens appear to have drifted from other places to where they are now found: the presence of mammalian bones and crocodilian remains are, however, indication that land was not far distant.

Lower Siwalik.—The rocks succeeding the Murree group in conformable sequence, where not faulted against it, are clearer and brighter grey sandstones and red clays, the uppermost parts of the clay bands having frequently grey or rusty tints. For want of a distinctive name which should not imply an identity not proved, I called these the "red and grey group," but they have since been traced into continuity with the lower and most fossiliferous portion of the Siwalik beds of the Jamu country: there is, therefore, no longer any doubt of their position in the series.

The passage is so gradual from the lower (Murree) group that the predominance of red over purple in the clays or a cleaner grey colour of the now softer sandstones afford but

* These have been noticed by Falconer and others as Attock fossils. The association of the name of that distant locality, where older azoic rocks only are found, is very inappropriate.

faint indications of a somewhat indefinite individuality. Finely concretionary pseudo-conglomeratic layers very similar to others in the group below are common, and conglomerate bands with derived pebbles from the underlying limestone and Murree groups, as well as quartzite, crystalline, or trappoid pebbles, are again met with. Fossil bones become locally more numerous, the upper part of this sub-division having furnished the larger number and most of the remarkable Siwalik forms found by Mr. Theobald in this district.

The Siwalik fauna has been long well known; still, as some of the forms from this region are new or otherwise interesting, I extract, from such published sources as are available, a short list of the names of fossils found in the district, with references to the sources of the information.

Major Vicary discovered bones and an *Elephas* or *Mastodon* tusk in the Lower Siwalik beds now traversed by the Trunk Road south of Ráwalpindi (1 of List, au. cit.).

Determined by Dr. Falconer, from near "Jalálpur and Lehri," 1854 (5 of List, au. cit.):--

Elephas, probably *E. hysudricus*.
Mastodon, species indeterminable.
Hippopotamus, resembling *Tetraprotodon*.
Rhinoceros, molars in fragments.
Equus, 2 species upper and lower molars.
Sus, upper jaw.
Sivatherium, lower jaw fragment with tooth.
Bos, upper and lower molars.
Cervus and *Antelope*, several species.
Camelus, portion of molar.
AVES, *Grallæ*, fragment of leg-bone.
Crocodilus and *Leptorhynchus* (*Gavialis*), vertebra jaws, teeth.
Trionyx, carapace and vertebræ fragments.
Fish, a vertebra.

Determined by Mr. Lydekker from the Khareán hills, south-east corner of map, 1874 (No. 21 of List, au. cit.):—

Equus Sivalensis.
Equus.
Bos.
Cervus.
Elephas hysudricus.
E. insignis (?) *Ganesa* (?)
Crocodilus.

Recorded by Mr. Lydekker from the district, Asnot, &c., 1876 (Rec., IX, 3, 4, Pal. Ind.—see List):—

Tetraconodon magnum, Falc.
An ear-bone of a *Cetacean*.
Listriodon and *Acerotherium*.
Bos, 4 new species.
Rhinoceros.
Lutra.
Hydaspidotherium megacephalum, n. g.
Dorcatherium.
Camelopardalis Sivalensis.
Merycopotamus Sivalensis.
Ursitaxus Sivalensis.
Hyæna Sivalensis.
Felis.
Ursus.

Determined by Mr. Theobald from south-west of Jand: *Bellia Sivalensis*, n. sp. 1877 (4 of List, au. cit.)

Besides these, many specimens await examination, amongst them the compressed shells of a fresh-water Mollusc (*Unio*) which I found in numbers at one locality (Saloi, south-by-east from Kahúta) in the upper portion of the group associated with crocodilian scutes, &c.*

Among the upper beds, but not with sufficient persistence to be everywhere distinguishable, is a thick zone of grey sandstones with few clay layers, generally of light drab or grey colour, and weathering so as to show elongated cores of harder nature than the rest. This has been called by Dr. Waagen and myself "the Dangót sandstone," from the lofty cliff of that name on the Indus near Kálabágh, in which it is conspicuous. There and in other

* *Unio* shells were also found many years ago by Mr. Theobald near Mount Tilla, at a spot which he has been unable to re-discover.

places it appears as nearly the highest band of the group underlaid by soft grey sandstones and brown or bright orange clays, but further to the east similar rocks to these overlie it. This sandstone usually contains scattered pebbles, or strings of pebbles, of quartzite, &c.; and where the overlying orange and grey rocks do not interrupt, it passes upwards by increase of the pebbles into the conglomerates of the highest tertiary group. Sections of 2,000 feet entirely formed of it have been met with. Mammalian bones occur but are not numerous in the Dangót sandstone. Similar thick sandstones, occupying the same general position, are found at the Jhelum side of the district, and the pebbly upper portion of the Lower Siwaliks seems to be most developed towards the eastern and western limits of the Potwár country.

Thicknesses of 4,000, 6,000 and 11,000 feet have been observed in this Lower Siwalik group.

Upper Siwalik.

This division includes the great conglomerates and associated beds which terminate the tertiary series of the country. Like all such deposits, these conglomerates are inconstant, admitting intercalations of the same kinds of soft grey sandstones and grey or orange clays as underlie them. Besides these, highly ferruginous and occasionally bright red clay bands appear. The conglomerate is in greatest force near the large rivers, as at Salgráon on the Jhelum, at Makad on the Indus, and forming the cliffs called Káffirkot between the Kurram and Bahádur Khel. The enclosed pebbles and boulders, ranging up to 18 inches in diameter, are almost entirely of metamorphic and igneous rocks, forming an extremely varied assemblage,* the mainly Himalayan source of which is indicated by the same detritus being still carried downwards in the channel of the Indus. Amongst these pebbles a fluctuating percentage of limestone occurs, some belonging to the Silurian (?), triassic, Jura, and hill-nummulitic beds of northern regions, and some few towards the Indus to *Alveolina* or coral-bearing rocks, supposed to have travelled from the westward. Away from the large rivers, as in the Soán Upper Siwalik basin, conglomerate beds, though less prominent, still appear, sometimes formed of limestone pebbles from the ranges to the north, or where the transported fragments are fewer, these include sandstone pebbles presumably derived from the Murree group.

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* For the advantage of obtaining the newest European names of some of these pebbles, I submitted duplicates of a quarter of a hundred to my friend Mr. Kinahan as an authority on the subject of rock names. The following are their designations according to him, quartzites predominating :—

1. Red and grey brecciated jasper (silicified shale).
2. Black pisolitic hornstone.
3. Red and grey pisolitic quartzite.
4. Purple felstone ("euyte") withblood-red specks, white and green silicious amygdala.
5. Black compact dolerite (aphauyte).
6. Red and green blended compact "slightly ophytic" felstone.
7. Purple granular quartzite.
8. Quartzose amygdaloidal euryte.
9. Granular purplish gray quartzite.
10. Hard green felsitic amygdaloid, tufoid.
11. Green amydaloid, white infusible amygdala.
12. Purple amygdaloid.
13. Gray and black speckled felspathic rock.

(To 13.) "These are all passage rocks between euryte and felstone, the 'Hybrid rocks' of Durocher."

14. Flesh-coloured quartzite.
15. Black hornstone with thin parallel lines of quartz (riband argillyte, silicified shale).
16. Hard purple felsitic trap (tufoid part of a euryte ?)
17. Coarse granular subcrystalline quartzite.
18. Saccharoid white quartzite or "greissen."
19. Banded purple and flesh-coloured quartzite.
20. Black argillyte.
21. Olive fine-grained quartzite.
22. Flesh-coloured and green mottled silicious rock (with nests of Olivine ?).
23. Compact green felstone, harder than a file.
24. Coarse flesh-coloured quartzite.
25. Fine-grained black pyritous quartzite (Itsberyte ?).

These must fall very far short of all the varieties of hard rocks among the pebbles of the Siwalik conglomerates. They were collected chiefly at the Jhelum side of the district.

In some parts of the district, the Upper Siwalik conglomerate masses are replaced by clays. This occurs south of the Bakrála ridge, and thence nearly to the Jhelum in a north-westerly direction. Again, in the valley of the Soán the group is represented by a mixture of very recent-looking sandy rocks and dull reddish clays, with an occasional dark, almost carbonaceous band; and numerous layers of gravelly conglomerate, or the limestone pebble beds already mentioned. To the westward near the Indus a thick deposit of drab and pinkish clays clearly overlies the conglomerates; it has furnished the Emydine described by Mr. Theobald, and other fossils (*ante*, 4 of List). Here, too, grey soft sandstones and orange clays are so intimately associated with the characteristic conglomerates as to have taken a considerable place in the upper group.

Siwalik mammalian remains are found in this upper division less frequently than below, and they often present a rolled or worn appearance as if derived from older beds.

In these Upper Siwalik beds, measurements of 3,600, 3,700, and 5,000 feet have been estimated from sections made to scale, and observations on the ground.

It will be seen from the foregoing descriptions that while different stages can be recognised in these tertiary rocks, their boundaries are somewhat conventional. The separation of the marine nummulitic rocks as the representatives of those in other parts of India or Asia, and the recognition of one great fresh-water series succeeding, would have marked the progress of more or less regular accummulation. Some of the beds, however, being clearly in continuation with sub-divisions of regions to the east (where more definite distinction exists), I have extended the classification to this ground as far as practicable.

Upon the estimates given, the whole series presents an aggregate depth of between 25,000 and 26,000 feet, or nearly five miles, of tertiary rocks. What terrestrial changes the time represented by the successive accumulation of such vast deposits may have witnessed, is beyond consideration here.

A few sections taken across the country, to show the manner in which the rocks occur, are appended. It should be remembered that the necessity for reducing their length to suitable compass renders them very diagramatic.

Unconformable Post-Tertiary and Superficial.—Large tracts of this district are covered by superficial accumulations resembling the alluvium of its present great rivers; indeed, owing to the rapid fall of these they are rarely depositing streams. Ordinary alluvium does, however, occur along their banks in places, particularly near the Lower Jhelum and Upper Indus. The older alluvium or silt very frequently predominates on the higher plateau ground, often cut through by intricate "*khudderas*" so as to show the underlying rocks. Sometimes it prevails in open depressions. Nearly all of it is more or less impregnated with soda salts (*Kuller*), rendering large areas difficult of cultivation, and, by facilitating the action of rain-water, increasing the rapidity with which "*khudderas*" are formed or extended.

Its colour varies considerably below, but the upper portion is nearly always a dull pinkish drab, glistening, finely micaceous and often distinctly stratified silt, in which "*kankar*" (carbonate of lime nodules) is locally abundant. Near Jand and Sagri, the silt is locally overlaid by loose blown sand, and it is everywhere undergoing transportation to lower levels. The saline nature and stratified condition of this silt suggest an estuarine deltoid or lacustrine origin; it has only been found to contain land shells of recent species.

Before the time of the deposit just described, certain of the larger depressions in the country existed, and some, such as the Soán, Sil, and Lower Hazára valleys, were unconformably occupied by coarse pebble beds and sand or clay. These pebble beds are not, however,

confined to the valleys; they rise out of that of the Soán on its northern side near Ráwalpindi, and seem to have once overspread a good deal of the country west and north-east of that station with strongly-marked unconformity. They overlie the sides of the Rotás gorge near Jhelum; occur near Nowshera on the Son-Sakesar plateau of the Salt Range; at Namal to the westward; and cap the mountain above Kálabágh on the Indus. In most cases, if not always, they are undisturbed; but rest at locally steep angles of deposition in one or two places (in the Park at Ráwalpindi, and Son plateau, Salt Range). In the Soán valley and towards Ráwalpindi the pebble-beds are chiefly formed of detritus from the limestone hills to the north, but the very layers consisting most largely of calcareous pebbles at the Pindi side of the valley, crossing the river, gradually change into a mass of light-coloured quartzite boulders, the original locality of which is as yet unknown. The unconformity so strongly marked near the Soán bridge on the Trunk Road is scarcely traceable in lower parts of this valley, though of course it exists.

In the Hazára and Chutch (Chaj) plains, the pebble rocks beneath the superficial silt, &c., appear as a coarse conglomerate or well-rounded gravel, chiefly of syenitic and gneiss fragments, overlaid by thick horizontal sands, sometimes consolidated so as to form a sandstone of almost precisely similar appearance to those of the upper tertiary beds, but enclosing subangular and rounded blocks of crystalline rock similar to the pebbles beneath.

Along the Indus and in the banks of the lower part of the Haró river these pebble and boulder beds are again seen, occupying different levels, chiefly in the lower part of the river deposits: similar post-tertiary accumulations form rather a high flat between the Mírkulán and Chíta hills, and the thick sands recur on the Indus near Sújanda.

North of the Mírkulán and Affrídi hills, detrital beds, apparently of the same group, were observed near Ispínhák, as saline yellow, pale pink, greenish, red and white sands, clays, and gravelly beds with bones,* or soft micaceous sandstone.

These coarse deposits, though not always present, seem to be transitional with the lowest layers of the silt, and this has not been observed to overlie the pebble beds in some lofty situations, where it may be doubtful that it ever was deposited.

The heights at which the post-tertiary beds are found range from about 800 to 3,000 feet above the sea; they have much the aspect of river deposits, and may have been formed at different periods.

Another variety of superficial accumulations, dating far back, though still forming, is the "wash" or "fan" detritus edging the Salt Range to the south, the hills near Banú, and those in the neighbourhood of Mírkulán and Pullosi passes towards Cherát.

Calcareous tufa ("kamát") is not an uncommon associate of the newer deposits. Sheets of it are interposed between the "pebble beds" and the underlying Murree group, upon the banks of the river Lé, near Ráwalpindi; others seem to have once overspread the ground near Fatahjang, and it is frequently seen among or near the limestone hills.

Erratics.—Dr. A. Verchere is believed to have first recorded the occurrence of large erratic blocks near Trap village on the Soán, attributing them to flotation by means of ice. These travelled blocks are distributed along the left bank of the Indus from Attock southwards, reaching into the country for ten or twelve miles from the river. They are more numerous between the parallels of Attock and Jand than further to the south, strewing the surface of the ground in patches, some being partially buried in the sand or other superficial accumulations.

* Major Vicary found the bone of a camel (?) in apparently the same beds at Akhora (au. cit.).

A group of these erratics occurs on the road between Jand and Kushálgarh; one is of granite, measuring over 15 feet by 9 feet by 3 feet (exposed). Others close by are of syenite, gneiss, hornblend schist, and black slate. For a few hundred yards around the ground is dotted with similar and smaller blocks, and others are numerously distributed over the neighbouring sandy country. Some of these appeared smoothed, but none that I saw showed any signs of striation.

Near the Tútal or Rais river opposite to Jand erratics occur again, but fewer. One of grey syenite measured 4 feet by 2 feet by 2 feet 2 inches; and a block of grey gypsum, 18 inches by 12 inches, was precisely of the kind occurring beyond the Indus in the Gúrgúrlot and other hills, or at Báhtar on the left bank of the river, where it crosses the Chíta range.

Two large erratics lie near the hamlet of Kummerallia (Wahlia of the maps) south of Daknér: one of white granitoid rock, weathering dark, has a girth of 50 feet and a height of 6 to 8 feet; the other, of basalt, is 48 feet 6 inches in girth and 12 feet 6 inches high. A block of grey felsite, set on end in the sand half a mile south of Hatti on the Trunk Road, forms a conspicuous monolith: it measures 8 feet 6 inches high by 18 inches by 6 to 10 inches. Not far to the north is a block of the Kyjnág and Hazára porphyritic granite with large twin crystals of felspar; it has dimensions of 9 feet by 3 feet 6 inches, and is much buried. There are others scattered about, but this one only suggests the northern source of these erratics with some certainty and the Indus valley as the direction from which they travelled.*

Far to the south-east near Hoon, Mount Tilla, Rotás, and in the Bunhár river at Ghoragali, smaller and less angular erratic blocks of red granite are numerous. One of these, however, at Narwari, a mile east of the Collector's bungalow at the Mayo salt mines (Khewra), is 7 feet in height, measures 15 feet in circumference at the ground, 19 feet half-way up,† and rests upon the red gypseous marl. These red crystalline boulders are supposed to have come from a peculiar conglomerate in the cretaceous or "olive group" of the Eastern Salt Range, or at least from the same unknown source as its enclosed blocks. One such boulder, polished and striated, apparently by glacial action, was shown me by Mr. Theobald, who found it in a wall near Wahali, on the eastern plateau of the Salt Range, not far from where the conglomerate just mentioned is *in situ*.

By what means these erratics were transported, if not by the agency of ice, is unknown. Their size, sub-angular shape, and the distances they must have travelled, favor this supposition. All do not seem to have wandered so much, thus localising the transporting cause: on one of the river terraces of the Indus gorge between Purri and Báhtar, I measured an erratic mass of unfossiliferous limestone 9 feet high and 74 feet in girth, which may have belonged to any of the neighbouring limestones from the lower nummulitic downwards, and seems to be as truly an erratic block as any of the others.

With regard to the existence of a glacial period affecting the Upper Punjáb in very recent geological times, the only evidence the country seems to offer is in the occurrence of the formerly Indus-borne crystalline fragments at heights some 2,000 feet above the present bed of the river. These would indicate either a very late elevation of the region traversed by the Indus, or that when it ran in a channel so much higher, the hilly country to the northward may have been as much more lofty (or even higher still), and regions of perennial snow much nearer than they are at present. The denudation, which, influenced by earth-movements, or alone, reduced the general surface, would have removed most evidences of

* I have also noted granite and other crystalline erratics at heights of four or five hundred feet above the Jhelum near Chuttur Kalas, the first stage from Kohála on the new road into Kashmir.

† From measurements kindly furnished by Dr. Warth.

glacial action,* and the widely spread, well-stratified post-tertiary silt would indicate aqueous conditions in the vicinity, which might have facilitated the distribution of these erratic blocks.

SUPPORTING ROCKS OF THE TERTIARY ZONE.

I shall now endeavour to convey as briefly as possible some slight idea of the palæozoic and mesozoic formations bordering the tertiary zone in this district.

SOUTHERN OR SALT-RANGE ROCKS.

The nine Salt Range groups of palæozoic and mesozoic formations, included in the list (*ante* p. 113) exhibit parallelism and conformity throughout; this, however, may be only a local, yet marked, peculiarity. Another as great is that the strata composing the sections at either end of the range are strikingly dissimilar. One formation or group may be traced thinning away and becoming overlapped by another at various points along it, so that in no place is the full section obtainable. Besides this the whole region has undergone most violent disturbance, resulting in displacement and contortion, sometimes one or both being prominent, and in places, owing to this, the oldest and newest of the groups are brought into contact. The outcrop on the scarped side of the range is thrown frequently into such intense confusion from land-slips caused by the deliquescent nature of the salt-marl that it is difficult to reproduce it on any map, and entirely impossible on the roughly reduced outline given with this paper.

"*Saline Series.*"—The red marl, gypsum, and rock-salt forming the lowest group is as mysterious in its origin as strange in its development and economically important, producing a large annual revenue of about £400,000 sterling. The salt occurs in the upper portion of a mass of red gypseous marl, and underlies massive, white, stratified gypsum. It shows a thickness of 600 feet at the Mayo mines, of which 225 are almost chemically pure salt (Dr. Warth's paper, No. 11 of list).

"*Purple Sandstone.*"—Thick sandstones, earthy below and of deep purple colour, becoming whitish at top, succeed the saline series. This "purple group" extends far to the west, but there becomes thin, and the sandstones give place to dark earthy conglomerates containing crystalline boulders of red granite and other rocks. It contains no fossils, so far as known.

"*Obolus beds.*"—In the next formation, however (also ranging widely westward), a belt of blackish clunchy shale, with sandy layers, was found to contain, at one or two places, the small detached valves of *Obolus* or *Siphonotreta*, a Silurian form, locally numerous, but entirely by themselves.

"*Magnesian Sandstones.*"—This group is to the east succeeded by, and connected with, a strong lightly coloured set of beds, the most conspicuous of which are hard, compact, magnesian layers, varying from dolomite to magnesian sandstone, and associated with flaggy and darker shaly bands, often covered with fucoidal and annelid markings. This formation has a more limited extension than the last, and was doubtfully thought by Dr. Waagen possibly to represent the carboniferous limestone of the west. From its position in certain sections, it appears to underlie that group, so I have preferred to keep it provisionally separate, particularly on account of its partial intercalation with the zone below, just where it is least recognisable to the westward.

"*Speckled Sandstone.*"—The next group is a massive succession of speckled light-coloured or reddish sandstones, with purple clays and conglomerate bands, the pebbles of which are chiefly of old crystalline rocks. At the top of the group, pale lavender clays (said to contain small concretions of copper pyrites) are constantly present.

* As pointed out by Mr. Croll would generally be the case (Climate and Time).

"*Carboniferous.*"—Immediately above these layers the carboniferous series commences in the Nilwán ravine, as dull, dark-coloured, impure, calcareous beds of small thickness. Westward the formation developes rapidly into a great mass of clear limestones, with some ferruginous or pale sandstones and dark earthy calcareous layers, the whole often crowded with palæozoic fossils, amongst which Dr. Waagen found the unique carboniferous *Ammonites* which he has described (*l. c.* No. 9 of list).

"*Triassic.*"—Almost united lithologically with this group is a series of thin limestones and greenish shales or clays developed from the Son plateau of the range westward, and containing abundance of *Ceratites, Goniatites,* and other forms, of the same genera but of different species from those in the carboniferous group below (as distinguished by Dr. Waagen). On the evidence afforded by these a triassic age has been assigned for the group, to which period also a group of bright red arenaceous and argillaceous rocks in the east part of the range, without fossils, but full of casts of salt-crystals, has been referred. It immediately succeeds the magnesian group before mentioned.

"*Jurassic.*"—Overlying the western triassic group are white soft sandstones, yellowish limestones, oolitic and earthy beds containing *Belemnites,* more rarely *Ammonites,* and other Jurassic fossils. The upper part of this Jurassic group becomes dark and shaly Trans-Indus at the Chicháli pass, where a curiously inverted and faulted section is exposed. Along their Western Salt Range boundary, the uppermost Jurassic and lowest nummulitic rocks present appearances of local transition through alternating bands of limestone, sandstone, and shale.

"*Cretaceous.*"—In some places, however, as in the eastern part of the range and at the Chicháli pass, dark-coloured shales and olive or yellowish sandstone with local beds of peculiar dark conglomeratic clay intervene between the above-named groups, or between the red trias (?) of the east and the coaly, shaly, ferruginous, or white sandy beds near the local base of the nummulitic formation. The shales in the Chicháli pass contain several globose *Ammonites,* recognised at once by Dr. Waagen as cretaceous; and I have found in these intervening beds (to the east) casts of large shells, which, with a few forms discovered by Dr. Waagen near Makrách, led to suggest for the beds a cretaceous age.

From the salt marl upwards, all the formations, as far as the base of the tertiary, seem to be marine; but as some are not fossiliferous, and there is a record of some plants found in the Jurassic group by Dr. Fleming, this is less than absolutely certain.

It will be seen that the contrast is strong between the rocks of this area and the pretertiary series of the outer Himalayan region.

WESTERN PUNJÁB, HIMALAYAN SERIES.

"*Crystalline.*"—The oldest part of this series includes the syenitic rocks, granitoid porphyry, and greenstones of Hazára (Pakli valley, Súsúlgali Agrór, &c.), and, from specimens brought down, it seems that crystalline rocks are common in Kaghán also. The granitic porphyry with its twin crystals of felspar, 5 or 6 inches high, is exactly like that occurring as erratic masses (from the Kyjnág range, &c.) near Nowshera in the Jhelum valley on the road from Murree to Kashmír.*

* This porphyritic rock seems to represent the central gneiss of Dr. Stoliczka's Himalayan sections (Mem. Geol. Surv. Vol. V); at least he appeared to identify a block we found together in the Jhelum at Huttí, Kashmír, with his "Albite granite."

"*Metamorphic and Silurian.*"—Over a considerable area outside the Hazára granitoid rocks, slightly metamorphosed, dull, talcose, silky slates were traversed, representing the local "Attock slates" of Nowshéra, Abbottabád, &c. Some of the altered beds (on the road from Manséra to Garhi Habibúlla, for instance) weather to a substance resembling porcelain clay. Greenstone dykes and masses intersect the inner portion of the slates, and syenitic protrusions occur, but no stratified or foliated gneiss nor any mass of quartzites or mica schists was met with, though such were known to Dr. Fleming among these mountains, probably at places which I did not visit.

In the Upper Hazára slates and those of Mianjáni mountain limestones are absent or uncommon, but occur extensively in the Gandgarh mountain north of Hassan Abdál, in the Attock hills and towards Mírkulán. These limestone bands have varied textures, from pseudo-brecciated to compact, and are often magnesian: one remarkable bed, though unaccompanied by other local metamorphism, resembles a clear sub-crystalline and compact white altered marble; it is slightly affected by acid. It stretches along the southern face of the Attock and Mírkulán hills. It is not improbable that several of these limestones, though closely associated with the dark slates, do not belong exactly to that series, but to some newer group. Others are undoubtedly interstratified.

In none of the slates or intercalated limestones have I been able to find a single organism; but in the hard limestones near Dakner, I found obscure traces of small gastropods and other shells, barely recognisable as organic: further west, at Mírkulán pass, these traces are stronger, and a few fossils can be distinguished.

The stratification of the slates is often obscured by a number of cross-cleavages, which render their furnishing slate of economic value unlikely. As a rule, they are very thinly laminated, this structure enabling slab or bedding slates to be raised where the cleavage is less prominent or coincides with the bedding; the material, however, is soft and weathers easily. Bands of dark-greenish, gritty, fine-grained sandstone are not uncommon. The whole group often shows intense folding and compression.

A possibly Silurian age for these slates has been chiefly inferred from the discovery of Silurian fossils by Dr. Falconer and Major Vicary in the Peshawar district, apparently not *in situ*, but traced to the Khyber mountains in Afghánistán. These fossils are stated to have been of lower Silurian age. Major Vicary mentions *Spirifer*, *Orthis*, *Terebratula* (?) and *Polyparia* in limestone. Similar genera occurring in the carboniferous and secondary rocks of the other parts of the country, the evidence as to Silurian age is limited, so far as any information at present available extends, to Dr. Falconer's fossils, as referred to by Major Godwin-Austen (in Quar. Journ. Geol. Soc. Lond. Vol. xxii, p. 29).

The slate group is perhaps older than carboniferous,* and may be a continuation of the azoic slates of Dr. Stoliczka's Himalayan sections.

"*Infra-Triassic.*"—Resting upon the Attock slates with complete unconformity is the series of Sirban mountain in Hazára (see Memoirs, No. 12 of List). The unfossiliferous red sandstones, hæmatitic and silicious magnesian beds, there underlying the triassic formation, are of unascertained age, and have not as yet been found elsewhere.

"*Triassic.*"—The triassic formation of the whole northern region consists largely of limestones often so slightly fossiliferous as to be very difficult to distinguish from those of

* Last season Mr. Lydekker found in a detached block near Hassan Abdál a specimen of *Productus Humboldti*, common in the Salt Range carboniferous formation. I have since searched the place in vain for any evidence of the existence of carboniferous rocks in the locality. It is possible that some may occur among the limestones on the south side of Gandgarh mountain to the north, though I failed to find a fossil of any kind in the only traverse of the mountain I have as yet been able to make.

the Jurassic period. Shales, limestones, silicious breccia, hæmatitic clays, and sandstones are present at Sirban; in other places limestones only are found, or with these a few shales, a sandstone band, or some ferruginous amygdaloidal clay. In one case I observed among other limestone rocks supposed to belong to this formation, a limestone conglomerate enclosing fragments of coralline limestone. The triassic beds are in force among the hills extending from the Mochpúra mountains to the Trunk Road; and a quantity of hard limestone, much of which may be triassic, appears in the Chíta range as well as in the detached hills to the north.

The fossils of the formation are, as a rule, scarce, obscure, and hard to detach: *Nerinæa, Neritopsis, Astarte, Opis, Nuculæ, Ledæ, Ostreæ, Terebratulæ, Rhynchonellæ, Megalodon, Dicerocardium, Chemnitzia* and *Gervillia* were identified by Dr. Waagen at Sirban, and *Ostrea Haidingeri* near Khairagali. At the western base of the Zyarut hill at Hassan Abdál I found a massive grey limestone bed unconformable upon Attock slates, and full of large *Dicerocardium* (and *Gervillia ?*) sections, the fossils being impacted and impossible to separate. Overlying this is a large zone of hard, thin-bedded limestones from which I obtained (loose) a very perfect *Pholadomya*. Sections of *Rhynchonellæ* are seen in the rocks, and on close search little *Retzia* (*?*) and Echinoderms are found weathered out. If the fossils of the upper portion of these limestones prove Jurassic, the unconformity between the trias and Jura of Sirban is absent here.

Thick, amorphous, splintery, nummulitic limestone of the paler hill-type caps the whole, and is compressed between the folds of the older beds, with very doubtful conformity to the thinner limestones below. In another section, near Kamalpur, of similar hard, thin-bedded limestone with some thicker bands, is a layer crowded with very large and thick *Ostreæ*.

The complicated association of limestones, trias, Jura, and nummulitic, extends westwards further than it can be followed into Affrídi territory (Afghánistán). "Large fossil oysters" are reported from a stream near Cherát, and at Mírkulán, not far from this place, there is the following succession, from south to north, a considerable part of which may be triassic:

Mírkulán Section.

(North.)

30. Dark Attock slates, with some harder bands.
    Fault (?).
    Upper Nummulitic.
29. Bright red earthy rocks and soft greenish sandstone.
28. Sandy limestone with large quartz grains.
27. Olive shales.
26. Strong purple sandstones.
25. Very red earthy rocks, cleaved.
24. Grey, slaty, olive and greenish shale, cleaved parts full of *nummulites*.
    Cretaceous (*?*).
23. Alternations of slaty shale and dark limestone with sections of *Cerithium* and *Natica* (*?*). Calcareous bands weathered to a rusty clay full of undeterminable fossils.

22. Thick limestone.
21. Dark greyish-green, slaty band.
20. Thin dark, flaggy limestones.
19. Greenish and grey limestones, highly contorted.
18. Thin-bedded black limestone.

17. Dark grey quartzite, with black flaggy slate bands, and white flaggy calcareous layers (600 ft.).
16. Silicious gritty beds.
15. Grey and purplish, rippled, thick-bedded slate (1,500 ft.?).
14. Grey, purple, and greenish flaggy limestone.
13. Dark green calcareous slates, thinly laminated.
12. White flaggy limestone with yellow lines, among grey slaty beds.
11. Dark grey and variegated limestone, magnesian, compact, with ferruginous strings; a black earthy layer and several shale partings, one hard blue band crowded with sections of thin flat bivalves, shelly parts often oolitic and contain sections of pentagonal crinoid stems.
10. Purple slaty band.
9. Black and greenish shining shale or clay, flaky; layers and nodules of grey oolitic limestone.
8. Black limestone—dolomitic in places, then of brownish grey colour.
7. Green-olive fine slate.
6. Strong grey and variegated yellow and black limestone: no fossils.
5. Brownish grey and purple slaty band, passing up into yellowish and green calcareous slate (about 200 ft.).
4. White flaggy lithographic limestone, thin and flaggy above, alternating with grey bands, like Solenhofen lithographic slate, upper part lavender-coloured.
3. Greenish olive; dark, shaly ferruginous, thin band (same as "Darwáza" limestone on Indus near Dakner).
2. Brownish yellow brecciated limestone, overlying.
1. Olive shales with ferruginous concretions.

The correlation of this section cannot be usefully attempted till the ground has received further examination. The series appears to rise in the direction indicated by the progressive numbers, but may be affected by faults and inversion in part. The southern end would seem to belong to the slate series; further on, the only guess which Dr. Waagen could hazard from the imperfect organisms found, wàs that the zone (so marked in the section) might be cretaceous; while the upper part, presumably faulted against the slates, is certainly nummulitic and perhaps upper nummulitic. The thickness exposed must be great, but could only be estimated for some of the zones.

"*Jurassic.*"—Jurassic rocks are known to exist in many places beneath the lower nummulitic beds. They, too, are chiefly limestones and not of widely different aspect from those overlying. In the southerly parts of these northern hills they usually contain a well-marked rusty zone, enclosing small grains of quartz, which give a rough appearance to the weathered surface of the rock. This zone is sometimes a mass of fossils, chiefly of large *Trigonia ventricosa*,* of which the matted and intertangled casts can only be obtained. *T. costata* occurs also, but the sections of the larger species give a very marked character to the weathered surface of the rock.

In the hills near Márgala pass, where broken portions of the Trigonia rock occur, the associated beds contain fragments of *Ammonites* and *Belemnites*. Again, to the west near Jang, the latter and *Gryphæa* abound in one or two layers just below the Trigonia bed. *Ammonites* of well-known Himalayan forms† are numerous in the Spiti shales of Chamba

* Determined by Dr. Feistmantel.

† *Oppelia acucincta*, Strachey, *Perisphinctes frequens* Opp.† conf. *Simplex*, Sow., *Belemnites Gerardi* Opp. *Inoceramus*, *Cuculæa* and *Pecten* are the fossils mentioned by Dr. Waagen. Records, G. S. I., Vol. V, para. 1, p. 17.

peak near Khairagali (where they were first discovered by Dr. Beveridge, R.A.). *Inoceramus* and *Ammonites* fragments, a *Pecten* and *Belemnites*, occur in another exposure of the Spiti group at Kondragali on the Abbottabád upper road from Murree; and some of these fossils re-appear in dark-coloured sandy and calcareous rocks far down in the deep ravine of the Haró below this locality.

None of these Jurassic rocks, Spiti shales, *Trigonia* zone, or the harder compact and semi-lithographic limestones in the least resemble the Salt Range Jurassic rocks, nor is there any similarity between the great trias limestones, &c., of the northern region and the *Ceratite* beds of the other locality. The cretaceous horizon of the northern area is chiefly marked by hard sandy limestones forming a thin band at Sirban and in the hills close to Kohát (though thicker limestones without fossils may also belong to the same formation). This band contains several *Ammonites*, a few *Baculites* and large *Belemnites*, generally of uncanaliculate forms. The aspect of the band is also quite unlike the dark shales of Chichâli or the "olive group" of the Salt Range.

Palæontological skill only can decide how far the northern and southern fauna are disimilar; to ordinary observation there is a striking difference between the fossils belonging to the formations of all ages from the two areas, corresponding with the lithological diversity, and suggesting much variation of conditions during palæozoic and subsequent times.

DISTURBANCE.

There are abundant instances of most intense disturbance and dislocation in this district, yet they appear to have resulted from but one extended influence, which produced the whole system of its mountain features. Strata belonging to all periods older than post-tertiary are contorted, but as no chronological sequence can be distinguished amongst the countless folds or numerous faults in any of the series, the whole of the disturbance connected with the physical features can only be attributed to a post-Siwalik period. Whether the results are due to one prolonged or to consecutive exertions of force, there is as little to indicate, as there is to show when the action ceased.

The marked line of disturbance, dislocation, and inversion along the outer Himalayan limestone hills has no counterpart in the district (unless a concealed feature of similar kind skirts the Salt Range on the south). It appears to imply special intensity of the disturbing agency. Other developments of extreme results occur;—a complete inversion of the Jurassic and tertiary limestones is seen among the hills between Shaladitta and Khánpur (northward of Ráwalpindi): inversion is common, sometimes extraordinary, all over the Kohát country, and its presence at Chichâli pass has long been known.

Although whole ages of apparently tranquil accumulation distinguish the succession in the Salt Range, the limitation laterally of so many of its groups may have been connected with slight or local alterations of level.

In the Himalayan area there are traces of palæozoic and mesozoic elevations and denudations, in the unconformities mentioned (at Sirban and Hassan Abdál), however local these may have been; and in the more central area, similar events in tertiary times are indicated by the derived fragments enclosed in the rocks.

The presence of the great tertiary sandstone and clay series of this area asserts the previous existence of an elevated region to the north, and its Siwalik boulder beds point to a west Himalayan elevation in later tertiary times, as plainly as the distribution of the same boulders in subsequent deposits proves that those western Himalayan regions have remained elevated ever since.

The lofty situations of these Himalayan boulders in some localities may either indicate a post-tertiary elevation or be a measure for part of the sub-aëreal denudation of the Upper Punjáb.

DESCRIPTION OF THE FIGURED SECTIONS.

These three sections, in consequence of the vertical exaggeration necessary, will show at a glance the general fall of the country towards the Indus from the Murree hills and Salt Range.

It will also be seen that the Himalayan side of the Ráwalpindi plateau is much the most generally disturbed, the folding of the rocks being almost confined in its greatest intensity to the Náhan-Sirmúr band and those groups lying northward of it. The local character of the Salt Range disturbances will also appear, but the sections do not happen to cross where these are most developed.

Section No. 1 is in two parts, from the difficulty of taking a single line over the most expressive features of the ground. In the part of it along the Trunk Road it may be noticed that the upper Siwalik conglomerates at and near the Rotás anticlinal are represented in the Khariân hills and south of the Bakrála ridge by clays. The faulting at the latter locality might be supposed sufficient to account for this, but from the aspect of the neighbouring country it appears equally probable that the formation has changed and the coarser beds have been replaced as at the Khariân ridge. The Náhan beds of Bakrála ridge have been already referred to.

The lower Siwaliks are largely developed from Mount Narh to the southward, giving sections of over 13,500 feet; and the upper Siwalik conglomerate beds have a thickness of 2,800 feet at Salgráon. The Murree hills are all formed of the rocks referred to the Náhan-Sirmúr group, but the contortion is so great that their thickness can only be guessed at about 5,000 to 7,000 feet, with the probability of its being very much greater.

The whole of the Kuldana spur, uniting the Murree ridge with the more lofty ranges to the north, is occupied by upper nummulitic beds, including a quantity of sandstones, &c., so similar to the overlying ones that their identity has been doubted. If the faulting necessary to have produced the present arrangement could be accounted for in detail, these questionable beds might be admitted to have belonged to the series above.

Northward from Kuldana the section has been already described, and its continuation to beyond the Miánjáni slates near Batangi shows alternation of nummulitic and Jurassic or triassic exposures, crushed and faulted beyond recognition of the geological relations. The mass of red rocks at Dungagali are believed to be upper nummulitic beds introduced by faults.

Section No. 2.—From Pind Dádun Khân to Gandgarh (or from the Jhelum to the Indus).—In this section one of the most conspicuous faults of the Eastern Salt Range is crossed, bringing a portion of the tertiary Náhan beds against the lower rocks of the palæozoic series. The land-slips and complexities of the Salt Range section here had to be omitted on account of the reduced scale of the section. North of the range the beds having most the appearance of the Náhan rocks may be taken at 1,500 feet, but beyond this the wide expansion of the lower Siwaliks rolling at gentle angles conveys little idea of the true thickness of the beds—a large one, however, in all probability exceeding 10,000 feet. The upper Siwaliks of the Soán basin may be estimated at from 300 to 500 feet, and are generally overlaid by the valley-deposits or loess, both series being in places so horizontal and so similar as to be hardly

distinguishable. At the northern side of this basin the beds become gradually tilted; the gravelly conglomeratic beds and clays pass down into the red and gray rocks of the lower group to near Khaire-Múrut ridge, where the angles are very highly inclined, or vertical bedding is found in the purple Náhan-Sirmúr group. In places on both sides of this ridge there are traces of the upper nummulitic beds intervening between the limestone of the hill and the purple rocks on its flanks, but the junction on either side as frequently has the appearance of a fault. Hence to the vicinity of Fatahjang numberless steep inclinations towards the north and south in the Náhan-Sirmúr rocks indicate the closely-folded and compressed curves of the beds, which are both disturbed and displaced at the upper nummulitic zone, as may be seen where the alternating limestones, shales, &c., mark the arrangement more distinctly. As an example of the contortion here I may mention that *thirteen* anticlinal curvatures are shown within 3,000 feet horizontally in one of Mr. Lyman's very carefully detailed sections at the Fatahjang petroleum springs, and there are many similar cases.

It not unfrequently occurs along the junction of the upper nummulitic zone with the stronger limestones of the adjacent hills, that there is a small space between the two occupied by rocks resembling those outside that zone. This is sometimes due to combined faulting and inversion, but the contortion is often so great that it is difficult to say whether there are not some intervening red and purple sandstones and clays really present. Sometimes also there are but very few layers of the well-developed upper nummulitic character to be found in their usual position, as at Shaladitta, where the main zone is a mile and a half to the southward, and the usual lower sandstones and clays of the Náhan-Sirmúr group, containing occasional layers of upper nummulitic type, are *faulted against*, rather than rest on, the Jurassic limestone of the hills.*

In this section (No. 2) the solid limestones of the Chíta Pahár range are of unusually pale colour, and sometimes full of nummulites. At the northern base of the range they are in contact with a highly disturbed and faulted zone of upper nummulitic beds. Further north the rocks beneath are concealed by heavy accumulation of valley beds (syenitic gravel and gray sands), until at Khaire Múrut the hard triassic-looking limestones show themselves in a folded state capped by and faulted against nummulitic limestone, below which the *Dicerocardium* and overlying limestones (some of them Jurassic?) of Hassan Abdál rest upon slightly exposed Attock slates, such as are seen with many intercalated and associated limestone masses on Gandgarh to the north.

In section No. 3 the carboniferous limestone of the Salt Range is shown appearing thicker than it is on account of the vertical exaggeration. The groups below it are the "speckled sandstone," "purple sandstone," and "gypseous" salt-bearing series, while the mesozoic formations above include the triassic Ceratite beds and Jurassic sandstones and limestones overlaid by the strong nummulitic limestone. The section continues through the same series as before, traversing the great upper Siwalik conglomerates of the Mokud region, the slightly fossiliferous bone and wood-bearing rocks of Jand and Nara, the upper nummulitic limestone and secondary limestones (probably both trias and Jura) of the Chíta range, then turning eastward in the river Indus traverses the valley deposits of the Kamalpur plains and the slates and limestones of the Attock hills, as shown in the section.

* Compare Records, Vol. IX, p. 156, para. 3.

NOTES ON FOSSIL FLORAS IN INDIA. *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

XIV, XV, XVI.

XIV.—ON A TREE FERN STEM FROM THE CRETACEOUS ROCKS NEAR TRICHINOPOLY IN SOUTHERN INDIA. (*With Plate.*)

AMONGST the fossil plants in the collections of the Geological Survey there is a portion of a tree fern stem from Trichinopoly, collected by Mr. H. F. Blanford from the same strata with the marine animal remains which yielded the numerous material for Dr. Stoliczka's monographs on the history of these fossils. Forms of the same kind have as yet been found mostly in cretaceous rocks at several pretty distant localities, on almost the same horizon, so that, if there were no information about our specimen, one might conjecture its being of cretaceous age.

If we look through the literature, we find (not regarding the carboniferous *Megaphytum* and *Caulopteris*, which have different characters) fern trees of this kind, first described and figured from Kaunic in Bohemia, by Comte Kaspar Sternberg*). This illustrous author, however, not knowing well the relations of the locality, and not knowing at that time any of the fossils which were later found associated with these stems, described them from the disposition of the scars and from their superficial resemblance with some stems of *Lepidodendron* and *Sagenaria*, as *Lepidod. punctatum*, Sternb., and the locality Kaunic as belonging to the carboniferous formation. Brongniart† described it even as *Sigillaria*, and also as carboniferous.

Prof. Gŏppert, 1836,‡ was the first to describe it as a fern, but placed it with the genus *Caulopteris*, species of which genus occur mostly in carboniferous strata. The same author described another species as *Caulopteris Singeri* from Silesia, which he later, however, united with that Bohemian species.

Presl, 1838, in Sternberg's *Flora der Vorwelt*, placed it with *Protopteris* as *Protopt. punctata*, and consequently the *Caulopteris Singeri*, Gopp., was also placed with *Protopteris*.

Corda § changed also the specific name to *Protopteris Sternbergi*, considering the locality, however, also as carboniferous (1845).

But soon after this, already in 1852, Prof. Reuss || mentioned that Kaunic does not belong to carboniferous, but is cretaceous, which in the subsequent year (1853) was quite distinctly shown by Prof. Krejci ¶ of Prague, who examined the locality, and proved that the sandstone wherein the *Protopteris Sternbergi* (*punctata*) was found is not carboniferous but cretaceous (cenoman.); he found again some stems of the same species, and also two new forms, of which one was named *Alsophilina Kaunitziana*, Dorm., and the other *Oncopteris Nettwalli*, Dorm., and figures of both were given with his paper, all being cretaceous.

In 1869 the same author** published an exhaustive report on the stratigraphical relations of the cretaceous formation in Bohemia, wherein, on pages 46 and 88-89, *Protopteris*

* Versuch einer Flora der Vorwelt, I. fasc. 1, p. 19, tab. iv. f. i. viii. 2.

† Histoire de végét. fossil p. 421, tab. 141, f. i.

‡ System filic. fossil, 1836, p. 449.

§ Corda Beiträge zur Flora der Vorwelt, 1845,

|| Jahrb. d. K. K. Geol. Reichsanst, Vol. III, n. 2, p. 105.

¶ Kounická Skála, in "Ziva," 1853.

** Archiv f. naturw. Durchforchung von Böhmen; geol. Sektion, IBd. Studien im Gebiete d, Böhm. Kr formation.

Sternbergi, Cord. (or *Caulopteris punctata*, Gopp.) is clearly described as from the lowest strata of the cretaceous rocks, the so-called Perutz-beds, near Kaunic and Vyserovic, so that there could no longer exist any doubt about it. Prof. Krejci did not, however, mention any fossils from the clays associated with the sandstones.

When in 1870 I joined the party for the geological exploration of Bohemia, I visited several localities in these lowest plant-bearing strata of the cretaceous rocks, especially the localities Nehvizd, Vyserovic, and Kaunic, east of Prague, and I saw the sandstone containing the fern stems intercalated with clay bands, in which were numerous plant-remains, consisting of some fern fronds, some coniferous branches, but especially *dicotyledonous* leaves, amongst which the peculiar genus *Credneria*, a typical cretaceous genus, was very frequent; in general the fossils agreed mostly with those described by Prof. Heer from Moletin in Moravia, and with those from Niederschöna in Saxony (as far as they are known), both which localities, as well as those in Bohemia, belong to the cenomanian; thus it was quite plain that *Protopteris Sternbergi*, Cord. (*Lepidodendron punctatum*, Stbg.), was a cretaceous tree-fern.

Also Prof. Römer in his *Geologie von Oberschlesien*, 1870, describes *Protopteris Sternbergi*, Cord., as distinctly cretaceous.

Subsequently, in my monograph on fossil tree-ferns from Bohemia* (carboniferous, permian, and cretaceous), I described the relations of these beds near Kaunic, which contain he *Protopteris Sternbergi*, and are cenomanian.

Previously to this Prof Göppert† had twice shown that *Protopteris Sternbergi* is cenoman, and placed his *Caulopteris Singeri* with it.

Prof. Heer in 1874 seems still to have known only the older descriptions of this fern as carboniferous, so that in his third volume of the *Flora Fossils Arctica* the locality Ujarasusuk of Disco in Greenland is described, from the occurrence of this *Protopteris Sternbergi*, as belonging to the carboniferous formation; but in a preface to the work he mentions a letter of mine to him on the occurrence of *Protopteris* in Bohemia, and then refers correctly the fern stem from Greenland to the cretaceous formation.

In Schimper's *Pal. végétale*, 1869-74, we find *Protopteris Sternbergi* still quoted as from carboniferous.

Its true horizon has been, however, fully confirmed also in other countries; the same fern was found in cretaceous (Unter Quader—Cenoman) of Saxony; ‡ and Mr. Carruthers § described it from the Upper Greensand in England (Shaftesbury in Dorsetshire), distinctly saying, on p. 485, that Dr. Fritsch of Prague has informed him that the beds from which *Caulopteris punctata* was obtained are Upper Greensand (cenoman).

In 1867 Prof. Unger || described a very nice fern stem from the cretaceous (Neocomian) near Ischl in Austria, to which our form from Trichinopoly is mostly allied. But Unger also was at that time quite unacquainted both with Prof. Krejci's publications about the tree ferns in Bohemia (1853), and with Carruthers' description of the same species from the English Upper Greensand, for he says, on page 648, that the Ischl species would be the first tree-fern in the cretaceous formation.

* Abhandl. d. K. böhm. Gesellsch. d. Wissensch. 1872, with two plates.

† Zeitschrift. d. D. Geol. Gesellsch, 1865, p. 643, and N. Jahrb. f. Min. etc, 1865, p. 396.

‡ Genitz Elbthalgebirge 1875, p. 304, Pl. 67, f. 1 (Palæontografica, Cassel).

§ Geolog. Magazine, 1865, p. 484, Pl. XIII.

|| Sitzungberichte der k. k. Acad. der Wissensch. LV, 1, 1867, p. 612, *et seq.*, Pl. I.

Quite recently I published a preliminary report on the flora of the cretaceous rocks in Bohemia,* where I speak especially in detail of the lowest beds (Perutz.-beds) near Nehvizd, Vyscrovic, and Kaunic; two sections illustrate the relations, and all the species determined up to that date are given. From this report it is quite distinctly shown how *Protopteris Sternbergi*, Cord. (*punctata*), is found in the sandstone, together with other species of tree ferns, and with cones of *Damarites*,† while the intercalated clays contain other plant fossils.

These beds in Bohemia with *Protopteris* are therefore cenomanian; so are the beds in Moletin in Moravia, and near Niederschöna in Saxony; also the locality in Saxony with Protopteris is cenomanian; the English locality is cenomanian too, and the locality in Greenland was afterwards (in the preface) referred by Prof. Heer also to cenomanian. Only Ungers' specimen is said to be from neocomian.

In Bohemia these beds contain, besides the plants, only some fresh-water and land animal remains, and are therefore fresh-water deposits; so seem to be also the beds near Moletin and Niederschöna. I am unacquainted with the relations of the English locality, and in Greenland these relations are also not quite clear. Prof. Unger's specimen was associated with marine animals.

The fern stems described from cretaceous rock up to date are as follows:—

1. *Protopteris punctata*, Presl. (Heer, Geinitz, Carruthers, etc.).—From Cenoman in Bohemia, near Vyserovic and Kaunic; Silesia (Giersdorf), in Saxony (Paulsdorf), in England (Shaftesbury in Dorsetshire), and in Greenland (Disco).

1828. *Lepidodendron punctatum*, Sternberg, Versuch einer Fl. d. Vorw. I, 1, p. 19, tab. IV, f. 1, VIII, 2. Described as carboniferous.
1828. *Sigillaria punctata*, Brongniart, Hist. d. végét. foss., p. 421, tab. 141, f. 1. As carboniferous.
1836. *Caulopteris punctata*, Göppert, Syst. filic foss, p. 449, etc. As carboniferous.
1845. *Protopteris Sternbergi*, Corda, Biträge, p. 77, tab. 48, f. 1. As carboniferous.
1852. Reus, Jahrb. d. k. k. geol. Reichsanst. Vol. III, N. 2, p. 105. Considered Kounic already as cretaceous.
1853. Krejci, in "Ziva." The locality Kounic is described quite distinctly as cretaceous!
1865. Göppert in N. Jahrb. f. Min. etc. Quotes *it* as cretaceous!
1865. *Caulopteris punctata*, Göppert. Zeitsch. d. D. geol. Gesellsch, p. 643, speaks quite distinctly of it as cretaceous!
1865. *Idem* Carruthers, Geol. Magazine, p 484, Pl XIII, from Upper Greensand!
1869. *Protopteris punctata*, Krejci, in Archiv f. naturh. Durchf. von. Böhmen, I Bd. p. 46, 88—89, described as Cenoman
1870. *Protopt. Strenbergi*, Römer in Geolog. v. Oberschlesien, p. 300, as cretaceous!
1872. *Idem*, Feistmantel Baumfarrenreste, Abhandl. d. k. Böhm. Gesellsch. d. Wissenschaften Distinctly described as cretaceous.
1869. *Protopt. Sternbergi*, Schimp. Pal. veget. I, p. 706. Again as carboniferous.
1874. *Protopt. punctata*, Heer. For. foss. Arctic, Vol. III. Quoted again as carboniferous from Ujaracusuk, Disco, but in the preface correctly referred to Cenoman.
1874. *Protopt. Sternbergi*, Feistmantel, Sitzb. d. k. Bohm. Gesellsch. d. Wissensch. December 1874. As cretaceous, Cenoman!
1875. *Protopt. punctata*, Geinitz. Elbthalgebirge, p. 304. From Cenoman at Paulsdorf in Saxony.

1*a*. *Protopteris Singeri*, Göpp. sp., and *Protopteris Cottai*, Göpp. sp., at first described as peculiar, were later (1865) placed by Prof. Göppert with *Protopteris Sternbergi* Corda.—Both also from cretaceous.

2. *Alsophilina Kouniciana*, Dorm. From Cenoman sandstone near Kaunic (Bohemia).

1853. Krejci-inZiva, Kaunická skála.—Plate.
1872. Feistmantel Baumfarrenreste, l. c.—Figure.

* Sitzungsb. d. k., Böhm. Gesellsch. d. Wissensch. December 1874.
† Mr. Stur's Lepidocaryopsis Westphaleni.

3. *Oncopteris Nettwalli*, Dorm. From Cenoman sandstone, Kaunic (Bohemia).

1853. Krejci, l. c., and 1872 Feistmantel l. c.

4. *Protopteris Buvignieri.*—From cretaceous near Grand Pré (Dpt. Ardennes).

1849. Brongniart Tableaux des genres. d. végét. foss., p. 111.

5. *Caulopteris cyatheoides*, Unger. From Neocomian near Ischl in Austria.

1867. Unger, in Sitzb. d. k. Acad. d. Wissensch. Vol. LV, p. 643—649, Tab. I, f. 1—4.

There are therefore up to date five species of tree ferns from the cretaceous formation all belonging to the same order.

If we now turn to our Indian specimen and compare it with the published figures, we shall find that it mostly agrees with Unger's species from Ischl, although the horizons are somewhat different.

Both these forms agree so much with the living *Cyathea*, that I do not see the necessity for classing them with *Caulopteris*, and I would propose for them the name *Protocyathea*

Genus PROTOCYATHEA, Nov.

Filix arborescens, caule tereti; cicatricibus ramorum (foliorum) spiraliter dispositis, nunc maximis nunc mediocribus, structura earum cicatricibus Cyathearum viventium proxima.

This genus would comprise two species, that one described by Unger as *Caulopteris cyatheoides* and our Indian form.

1. PROTOCYATHEA UNGERI, sp. nov.

1867. Caulopteris cyatheoides, Unger., l. c.
1869. Schimper, Pal. végét., I, p. 708.

Locality: Neocomian near Ischl in Austria.

2. PROTOCYATHEA TRICHINOPOLIENSIS, sp. nov., Pl. I, f. 1-2.

Caule arborescente, vivo tereti, statu fossili compresso, 10 Cm. in diametro metiente, extus cicatricibus ramorum (foliorum) notato; cicatricibus confertis, spiraliter dispositis, oblonge rhombeis, parte inferiore acuminatis, parte superiore obtusiusculis, fossula separatis; disco convexo prominente, subrhomboidali, vasorum stigmatibus circumdato, intus nonnullis vasculis sparsis notato; inferiore parte cicatricis stigmatibus majoribus expleta. Cortice partim tantum preservato.

The stem is a little compressed and preserved in fine-grained, pretty hard sandstone. It cannot have been very thick, the diameter of the compressed specimen being 10 Cm. The chief character is the scars; they are disposed in spiral order on the outside of the stem, the spirals being pretty vertical. The form of the scars is oblongly rhomboidal, in the lower portion more elongated and acuminated, in the upper portion obtuse; and here pretty convex and prominent (the disk); the scars are pretty closely set and separated by furrows. The discal portion is limited by roundish vascular marks from the other portion of the scar, and the inner surface of the disk contains some other vascular marks. The lower portion of the scars, which is elongated, contains also several larger and more oblong grooves.

To show these grooves in the lower portion of the scars I have added in fig. 2 the view of one scar, which exhibits them very distinctly in form and disposition. They are especially well seen in the scars of the lower portion of the stem, where a little of the stem-substance is preserved.

Regarding the living affinities, we find that our specimen is next related to *Cyathea compta* (see Brongniart, Hist. d. végét. foss., Pl. 42, f. 1), where the discal portion equally is surrounded (limited) by closely set vascular marks as in our fossil form; also in the inner surface of the discal portion seems to be a similar disposition of the marks. The only difference would be that the scars in our specimen are not so distant, and that the marks in the lower portions of the scars are much more numerous in our fossil.

In Hooker's *Species Filicum*, p. 42, I found, however, the *Cyathea compta*, Mart., described as *Alsophila compta*.

Amongst the fossil forms, the next relation of our fossil is with *Protocyathea Ungeri* (*Caulopteris cyatheoides*, Ung.), which is apparently also a *Cyathea*, and Prof. Unger himself has compared it with *Cyathea compta* and *Cyath. vestita*. I have only to refer to his paper (l. c.).

Our species is therefore to be added as a sixth form of tree-fern from cretaceous rocks in the table given above.

Explanation of Plate.

Fig. 1. The stem in natural size.

Fig. 2. One scar specially figured to show the stigmata in the lower portion.

XV.—NOTES ON THE KARHARBÁRI FLORA.

In two previous papers in the Records (Vol. IX, 3, 4) I had mentioned several fossil plants from Karharbári, which were brought to our knowledge by Mr. Whitty, Superintendent, Karharbári Collieries, East Indian Railway. This year I had an opportunity of visiting the coal-field myself and of collecting fossils, in which I was very much assisted by Mr. Whitty's knowledge of the ground. The flora yielded the interesting fact that it is more related to that of the Talchir shales than is the coal flora in any other field (at least as far as brought to notice at present, except the plants from the Mohpáni coal-field). This relation is also supported by the stratigraphy, both series in this field having the same dip, and being apparently in conformable sequence.

The Talchir flora, as known at present, is very poor, but all species of the real Talchir shale were found again in the Karharbári coal strata. The other character of the flora is, as will be seen, to a great extent triassic, very many forms being like those which European geologists are used to call triassic.

I know at present fossil plants from seven localities in this comparatively small coal-field, and it is to be expected that others will be found.

The localities are—

1. *Buriádi*, yielded ten species and four varieties of one species.
2. *Chunika*, containing one species.
3. *Domaháni*, with five species and two varieties of one.
4. *Passarabhia*, with six species.
5. *Máthádi*, with two species.
9. *Jogitand*, with four species and two varieties.
7. *Komaljore Hill.*

In all these localities the flora shows very much the same character, some species being common to all.

In the Talchir shales themselves I could not succeed in finding any fossils, but I observed very well preserved ripple-marks in the shales.

I shall only shortly give here a sketch of the flora, postponing other details for a future time, when I can give illustrations.

EQUISETACEAE.

Forms of this class are not so frequent, as in the Damudas, elsewhere.

Some stalks, rather shortly articulated, with small cicatriculæ in the joints and fragments of free leaves, are to be referred to *Schizoneura*, and are next to *Schizoneura Meriani*, Schimp. (*Equiset. Meriani*, Bgt). They are from Passarabhia. From Komaljore Hill *Schizon. Gondwanensis* is known; two similar stalks occurred in the Talchir shales.

Vertebraria is very rare; near Passarabhia some small fragments occurred.

FILICES.

The greatest display of forms is in this class. A large *Neuropteris*, belonging to the triassic single-pinnate type of this genus, occurs very numerously near Buriádi. I have already described it as *Neuropt. valida*; it is very close to *Neuropt. gigantea*, Schimp. and Moug., from the Bunter in the Vosges. The genus *Gangamopteris* is very frequent beside this in all localities; most forms belong to *Gangamopteris cyclopteroides*, which I have previously described, and of which I now could distinguish four varieties. This species was first known from the Talchir shales.

Besides *Gangamopt. cyclopteroides* and its varieties, there are three other species of this genus from Domaháni, Buriádi, and Jogitand. *Glossopteris*, in the true form, is rather rare in the coal-field, and only in two localities more frequent; and I think this species belongs to my *Glossopt. communis*. It is from Passarabhia and Máthádi. From the Talchir shales in the Káranpura coal-field also a specimen of *Glossopteris* is known.

From Buriádi there is known a peculiar form, which shows the transition from *Glossopteris* (real) to *Gangamopteris*, or *vice versâ*. I called it *Glossopt. decipiens*, the midrib of which is quite distinct in the lower two-thirds, vanishes towards the apex, where the secondary veins are radiating.

With the ferns having net-venation *Sagenopteris* is still to be placed.

CYCADEACEÆ.

Cycadeaceæ are pretty frequent amongst the fossil plants from Karharbári coal-field.

Zamia Hislopi is very frequent, but longer than the usual form, and I call it therefore var. *prælonga*; in all localities and in Talchir shales. Another very nice *Zamia* shows two leaves attached to the stem; I call it *Zam. Whittiana*, from Buriádi. A *Glossozamites* also occurred near Domaháni. This species I have described shortly in a previous note, and called it after Dr. Stoliczka.

CONIFERÆ.

Some triassic forms are pretty frequent amongst the plants of this coal-field. They are from Domaháni ghât and Buriádi.

I can determine altogether eighteen species and some varieties. Amongst these are all the plants which are known also in the Talchir shales; besides these there are some triassic

types, and some local forms. This, I think, tends to show the close connection of the Karhárbari coal strata with the Talchir shales; and the evidence from the plants speaks strongly for a triassic, or at least mesozoic age of these strata. The bearing of this conclusion upon the age of the Damudas in other fields needs not to be pointed out.

From the vegetable remains in the Talchir shales, which are as well preserved as in the coal-beds, the conclusion would follow that the Talchir shales must have been deposited rather under similar conditions as the coal-bed, and different from those under which the boulder bed was formed.

XVI.—On the occurrence of Glossopteris in the Panchet Group, and in the Upper Gondwanas.

When reporting in the last number of Records (Vol. X, 2) on some fossils which I collected in the Nunia stream north-west of Assensole, I suggested that some beds above the outcropping coal seam might, from their stratigraphical position, be considered as associated with those which were distinguished as the Panchet group, although *Glossopteris* occurred in them. I added that I had no doubt that this genus passes into the Panchet group. Already in 1861 Mr. Oldham mentioned a *Glossopteris* fragment* from the real Panchet rocks, as described by Mr. Blanford.† Mr. Oldham says:—"There are a few mutilated and drifted fragments of fossils beside, one of which (fragment of one side of a frond) shows the existence of *Glossopteris*, undistinguishable save generically." And the same is repeated again by Mr. Oldham on page 206 in the same paper, so that already at that time there was no mistake about it; but later, it seems to have been generally supposed that no *Glossopteris* exists in the real Panchet group.‡

To satisfy myself how the matter stands, I made a search through all our collections of fossil plants from the Raniganj field in the hope of finding the specimen mentioned by Mr. Oldham. I succeeded in finding about eight leaf fragments, just in those specimens of the rocks which are full of the small *Estheria*, allied to that in the Mángli beds. The *Glossopteris* remains are mostly only fragments of the leaf, but peculiarly well preserved, and one can see the reticulations without the lens, some (about 3), however, show distinctly the midrib, from which the secondary veins pass out, forming distinctly meshes (see figures). Thus there can be no doubt that *Glossopteris* existed during the deposition of the Panchet group. This manner of preservation resembles that in the Kawarsa beds of the Chánda district, where *Glossopteris* occurs also in a very fragmentary state, and again associated with *Estheria* (the form as in the Panchets and in the Mángli beds). In my note on the *Estheria* beds in India §, I have already pointed this out, and I repeat again that the Kawarsa beds very likely are on the horizon of the Panchets in Bengal.

We have thus in the real Panchet group *Schizoneura* and *Glossopteris*, both of which occur again in the underlying Raniganj group; and the Panchet group is certainly as closely connected by fossils with the Raniganj group, as the Mángli beds are with the Kamthi (Raniganj) group. Mr. W. T. Blanford himself found no great unconformity between the Raniganj and Panchet groups. On page 127, l. c., Mr. Blanford says:—"It should, however, be remembered that there is a very considerable apparent conformity between the two groups,

* Additional remarks on the geological relations and probable age of the several systems of rocks in Central India, etc. M. G. S., Vol. III, p. 197, *et seq.*

† On the geological structure and relations of the Raniganj coal-field, M. G. S., Vol. III, pp. 3 and 126.

‡ See a letter by Dr. Oldham to Rev. W. B. Clarke, published in his "Remarks on Sedimentary Rocks of New South Wales," 3rd edition, page 29.

§ Rec. Geol. Surv., X, 1, p. 29

and that excepting in the section on the banks of the Nunia,* the want of it can only be made out by a careful comparison of the rocks of each formation over considerable areas.' And Mr. Oldham, in his paper mentioned above, says about this unconformity:—"The unconformity between them (Raniganj and Panchet groups) is but slight (in truth, such as would never probably have been noticed were the change, from one group to another, not marked by a change in mineral characters of rocks), etc." I went myself twice through this part of the Nunia stream, and I could only observe this apparent conformity, and the co-existence of *Schizoneura* and *Glossopteris* in these beds, and therefore their close connection with the Raniganj group cannot, I think, be denied, whatever may be the differences in mineral characters.

Amongst the fragments of *Glossopteris* which I mentioned above in the specimens of the Panchet rocks, there are easily seen two different forms of areolation: one is that of *Glossopteris indica*, Schimp., and the other of my *Glossopteris communis*. I may thus record the fact that *Glossopteris occurs in two forms in the true Panchet rocks, together with Schizoneura and Estheria*, connecting the Panchet group more closely with the Raniganj group than I supposed before.

But I have also to notice the occurrence of *Glossopteris* in the "upper series" of the Gondwána system,—in the Jabalpur group and in the Denwa groups.

There are some specimens from the Sher river amongst our Jabalpur fossils; one of these I described as *Cyclopteris lobata*, comparing it with the *Cyclopt. digitata* from the English Oolite; but it is also very close to those forms which only recently were described by Heer from Middle Jurassic (oolitic) strata in Greenland and Eastern Siberia as *Gingko*, to which also *Cyclopt. digitata* from Yorkshire was placed, and it would be the case also with our form. On the reverse side of this specimen I discovered the first specimen of *Glossopteris;* by splitting the stone I uncovered another leaf of this genus.

There is another specimen with *Alethopt. Whitbyensis*, Göpp., also from the Sher river, which contains also two leaf fragments of *Glossopteris*. Although fragmentary, the existence of the genus *Glossopteris* in the Jabalpur (Kach) group is unmistakably proved.

In 1875 Mr. H. B. Medlicott brought from the Denwa horizon (Mahadeva Series) of the Satpura basin near Kesla, some specimens of a very crumbling rock with fragmentary plant-remains, amongst which is a leaf, the venation of which is areolated, and which I can only believe to be a *Glossopteris*, with which also the whole form of the leaf agrees. I have no intention to determine the species; I am satisfied with the generical determination. By these discoveries, I think, *Glossopteris* loses somewhat of its "exclusive carboniferous character," which in Australia is given by the marine fauna, while here in India I believe it to be mesozoic.

ON THE OCCURRENCE OF ERRATICS IN THE POTWAR, AND THE DEDUCTIONS THAT MUST BE DRAWN THEREFROM, *by* W. THEOBALD, *Geological Survey of India.*

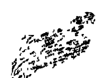
As my assertion of the former extension of glaciers to so low a level as 2,000 feet in the Kángra Valley has found scarcely more favour at the hands of my colleagues than from the author of *Fire and Frost* (*vide* J. A. S. B., 1877, Part II, No. 1., p. 11), it is some satisfaction to me now to produce additional evidence tending to the same conclusion; and if I am not mistaken, less open to the destructive criticism of experts than were my rather crude observations in Kángra.

* The above-mentioned specimens, with *Estheria*, *Schizoneura*, and *Glossopteris*, are from here.

3

2

4



5

6

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8

Indeed, my present evidence goes farther than that of the so-called and so-disputed Kángra erratics and moraines, for in their case I merely argued for a terrestrial or moraine origin which did not exclude the probability of a sufficiently great difference of level in the whole country to largely obviate the isothermal difficulty, whereas I now am forced to contend for floating ice as the vehicle of my Potwár erratics, and this almost precludes the idea of any considerable difference of level between then and now along the Indus basin, the conditions of the problem rather necessiting the supposition of the Potwár then forming a vast lake subsequently drained by the lowering of the Indus bed above Kálabágh.

I will preface my remarks by saying that by the term "erratic," I understand fragments of stone of any size or shape which have been transported by ice, and that the occurrence of blocks of stone (neither meteoric nor presumably due to drift timber), embedded in thinly laminated impalpable silt, is *primâ facie* evidence of ice as the transporting agent.

The Potwár is that vast spread of undulating open ground north of the Salt Range. It is sparingly marked with hills, and rendered somewhat difficult to traverse by deeply excavated streams and ravine-ground, the result of atmospheric denudation acting on a soft alluvial surface. The surface is mainly alluvial, but the underlying Siwalik sandstones often crop out above the surface, or as frequently display themselves in the deep sections afforded by streams and ravines.

The alluvium—or loess, as it has been proposed to be called by some writers—is very variable in character; most generally it is a brown clay, with little or no *kankar* (lime-nodules) in it, and very prone to melt away before rain action; hence the deep intricate ravines which intersect it.

In some spots, as south-east of Fatehjang, towards the Khaire-Múrut range, it presents the character of a lacustrine marl, with thick beds of earthy tufa crowded with land and fresh-water shells, among which I remarked—

Lymnea rufescens L. (probably a var. of *L. peregra*).
Planorbis exustus.
P. convexiusculus.
Vivipara Bengalensis.
Bythinia pulchella.
Melania tuberculata.
Corbicula (a small species near *Agrensis*).
Unio (near *Candaharica.*)
Macrochlamys Jacquemontii.
Cylendrus insularis.
Napæus salsicola.
Opeas gracilis.

At other places where less tranquil deposition was taking place, the alluvium has the character of ordinary river deposits, clay, sands, and gravels intermixed; whilst east of Ráwalpindi these gravels are replaced by coarse boulder conglomerates with an aggregate thickness of over 200 feet, and possibly much more, as denudation has largely modified the surface of these beds.

Near Jand a considerable area exists of a fine thin-bedded silt wholly devoid of organic remains, and therein presenting a striking contrast to the equally fine, though dissimilar, clay or marl at Fatehjang. A considerable thickness of this silt is seen (40 feet at least), but its relation to the ordinary alluvium is obscure, it being covered over and masked by enormous quantities of blown sand carried over it from the bed of the Indus by the powerful west winds blowing in the hot season. This silt is impalpably fine and thin-bedded, and of an extremely pale greenish fawn colour, and *in it* are impacted masses of granitoid gneiss, such as constitute the biggest erratic blocks of the district about to be enumerated. One such block, a little under a foot in diameter, was seen in a road-side section north of Jand, impacted *in situ,* and but half exposed by denudation in this silt, the fine laminæ of which were curved against it, as would be in the case of a foreign body embedded in such a position.

This block is not a particularly large one, though its presence in so fine a bed demands a special explanation, but it is valuable as clearly displaying the fact that some, at all events, of the erratics which overspread the surface are weathered *in situ* out of a lacustrine silt indicative at some former period of both lacustrine and glacial conditions in the Potwar.

Near the burial-ground of Jand a deep section of this fine silt is seen, and on it another erratic is seen of about a cubic yard in contents, and this, there seems no reasonable doubt, has also weathered out *in situ,* though it is not so self-evident as in the other case.

It will hardly, I think, be contended that these erratics were transported by floating trees, for this reason, that they are random samples of that spattering of similar blocks many of which are too huge to be capable of any other transport than ice; and this embedded block at all events, from the nature of the materials which surround it, could have been transported by no debacle or even moraine, but must have quietly sunk where it now lies.

The first erratic noticed by me (being first discovered by apprentice Kishen Sing) was in a small stream less than a quarter of a mile west of Pind Sultáni on the road from Ráwalpindi to Jand. At this spot two blocks of a gneissic rock, which probably once formed a single fragment, are seen lying half buried in the sand of a small stream. The larger fragment is nearly ten feet in its greatest length, and nothing approaching this size is seen in the ordinary surface gravel, or in the section of the banks of the stream wherein these blocks lie. Scatttered blocks of a similar gneiss, but of a smaller size, occur at several spots along the road as far as Jand, near which place they are not very uncommon. These fragments are more or less angular, and have nothing in common, so far as appearance goes, with the ordinary rounded boulders and gravel of the Indus, a spill of which materials is found all over the country as we near the Indus, the remnants no doubt of a former high-level deposit of gravel and boulders swept down that river and its tributaries.

About two and a half miles west-north-west of Jand, and a little south of the road to Kushálgarh, occurs a monstrous fragment of gneiss forty feet in girth, and sundry smaller fragments are seen in the neighbourhood, as also a little nearer the Indus; but close to that river these fragments disappear, or are involved undistinguishably in the general mass of boulders swept down in its bed. There is at the spot where this large block occurs much surface gravel, but the rock beneath seems to be the silt I have previously described, which here sheets over and fills in the hollows between the harder Siwalik ridges which here and there crop out above the surface. So obvious is the foreign character of this granitoid rock resting on fine silt, that it has acquired a legendary fame, and is resorted to as a cure for fever, which is effected by the devout pacing it nine times without drawing breath.

The distance between this block and that first noticed at Pind Sultáni is twelve miles, and the direction of the line joining them east-north-east, west-south-west. Along this line small angular erratics are here and there seen, none more than a mile on either side of it; which clearly indicates the linear arrangment of these blocks. To establish this fact I made a traverse to the north as far as Jalwal, besides despatching Kishen Sing in other directions, but without finding any other blocks save those mentioned; whilst to the south I made several traverses equally without result, till the second line of erratics was met, the intermediate ground being free from these fragments. At twenty miles, however, south-east of this line of Jand erratics, a second line of them is met with possessing the same general strike (east-north-east) as the last, and this line I traced for eighteen miles along the course of the Soán river, which must have engulphed many in its sands. This line extends through Shah Mahomedwalla and Jabbi, and some of its fragments are found two miles or a little more on either side of the centre line. The most easterly fragment noticed was a huge mass broken into several pieces, over 20 feet in girth, resting on alluvium at a high level eight and a half miles from Pindigheb and eleven miles from Jaman, and there are several

smaller blocks in the same neighbourhood. An equally large block occurs close to Suriali six miles to the south-west, whilst six miles north-west of this last occurs another not quite so large. These two last blocks are the most divergent, being five miles apart, and between them the great central course of blocks seems to pass. Below Shah Mahomedwalla, erratic blocks, mostly of gneiss, are numerous, but above that village the Soán has engulphed them, or the blown sand in the low land south of the river has covered them up. Enough, however, remains clearly to establish the fact of their being two trains of erratic blocks in the Potwár, many of which blocks range from 20 to 40 feet in girth, and some of which at all events are impacted in a thin-bedded silt. These two trains of blocks are twenty miles apart, and their course very nearly at right angles to that of the Indus, but coincident with that of its main feeders in the area in question at the present day (the Soán, etc.).

My colleague, Mr. Wynne, has also found numerous erratics, with an excellent sketch of some of which he has kindly supplied me, but beyond a mere announcement of this corroborative fact I need not now go. The discovery of one or more pieces of the dark Trans-Indus gypsum has, I believe, led my colleague to entertain a suspicion that these erratics have travelled from the west; but this I think must be viewed with the utmost caution, as whether we regard the erratics as borne by floating ice or not, it is hard to concieve that any train of blocks coming from the west would pursue (as I have shown the Potwár erratics to do) a course to the east-north-east.

The above simple exposition of the few facts bearing on this interesting question, gathered by me in the course of my last season's work, must suffice for the present, as till we know more of the direction whence these Potwar erratics descended, speculation on the subject would be vain. One thing, however, I regard as established,—namely, that whilst glaciers were ploughing their way down the great Himalayan rivers and valleys to within 2,000 feet or so of the sea, the Potwár was one great lake, with an exit probably near Kálabágh as now, and into which lake glaciers descended freighted with the debris of the hills of Hazára and Kashmír.

W. THEOBALD.

Dharmsala, June 1877.

ON RECENT COAL EXPLORATIONS IN THE DARJÍLING DISTRICT, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

AT the time when the construction of the Northern Bengal Railway was commenced, the Government of Bengal, in view of the importance of obtaining, if possible, a supply of coal within a distance less great than that from the known coal-fields of Ránigan) or Kaharbári, requested that an examination should be made into the mineral resources of the Darjíling hills, with reference more especially to coal. To this duty I was deputed during the cold weather of 1873-74. The results of my work are included in Part 1, Vol. XI, of the Memoirs of the Geological Survey.

In that report it was shown that a narrow band of Damuda rocks stretches from Pankabári eastwards as far as Dálingkot, at an average distance of two or three miles from the base of the hills. The strata, however, have undergone great crushing and distortion, and are tilted up on edge, dipping generally at a high inclination: often vertically, and seldom at lower angles than 30° or 40°. Such disturbance is accompanied by great change in the lithological characters of the rocks, the sandstones and shales being frequently converted into quartzites and slates, respectively, while the coal has lost a large proportion of its

volatile matter, so as to approach to anthracite in composition. At the same time the crushing to which the seams have been subjected has squeezed them so that they often vary greatly in thickness within a few yards, and has induced a flaky structure in the coal, which renders it so friable that it can be crumbled into powder between the fingers with the greatest ease. With respect to the economic value of the coal, it was pointed out that owing to the high inclination of the seams; their rapid variations in thickness, as well as in dip and strike; the shattered condition of the rocks in many places, and the friable state of the coal, great difficulties were to be anticipated in any attempt to mine the coal; its powdery condition also rendering it useless as fuel until after conversion into either coke or patent fuel.

Considering that the friable condition of the coal was almost beyond doubt due to crushing during the period of elevation of the Damuda rocks, and not to mere atmospheric influences, the opinion was expressed that but little hope of improvement at a distance from the surface could be anticipated. At the same time, the value of workable coal in this part of India would be so immense, even if workable with difficulty, that it was recommended to place this point altogether beyond doubt by driving trial drifts for some distance into one or two of the more favourably placed seams. From these drifts some information would also be gleanable as to the steadiness of the seams with respect to thickness, &c. A seam at Tindháría of 11 feet at the outcrop, and another in the Chirankhola jhora of about 6 feet, were recommended for these experimental openings. Subsequently, however, it was determined to drive into the former of these alone.

The work was placed under the direction of Mr. A. H. Tyndall, Executive Engineer of the Darjíling and Jalpaigori division. In such treacherous ground, with men wholly unaccustomed to work of the kind, the difficulties encountered were by no means small. The hill coolies were most unwilling to work underground with the possibility before them of being buried alive, and two explosions of fire-damp, although they did but little damage, were not calculated to reassure their minds. Neither were they much encouraged by a fall of earth which closed up the mouth of the mine one day just as they were about to enter it for the day's work. Some copper miners from Sikkim, who are accustomed to burrowing in the ground, and who it was supposed would make no difficulty about the matter, were engaged, but on seeing what was wanted, and that the excavation was not in the hard rock they were accustomed to, they declined to have anything to do with it.

The outcrop where the drift was commenced is in the bed of a small stream (about 200 yards south-west of the Tindháría bungalow), from which the ground rises steeply on both sides, the seam crossing the rivulet nearly at right angles, and heading straight into the side of the hill. Work was begun by cutting away the superficial earth and exposing a vertical face at a distance of about 10 feet from the original outcrop. From this point the adit, 4 feet 6 inches high by 2 feet 6 inches broad, was driven, with an upward inclination of about 5 degrees to allow for drainage. Cross-cuts were made at intervals to determine the thickness of the seam. In April last the excavation had been driven to a depth of about 100 feet from the entrance, when the miners were suddenly brought to a standstill by coming on solid sandstone. I was consequently directed to proceed to the place and examine the drift. The accompanying plan* shows its course with reference to the seam, and the cause of the apparent discontinuance of the coal. Owing to a twist of the seam towards the right, the miners got, near the fourth cross-cut, into the dark brown shale, containing some coal, which underlies the main seam, and, penetrating this, came on the sandstone below.

* I am indebted to Mr. Tyndall for the topographical features.

The main object of the drift—the determination of the question whether the coal improves at all in the interior—has however been satisfactorily accomplished, the seam having been followed to a distance of about 80 feet from the original outcrop; and owing to a small land slip which took place last rains, two outcrops have been exposed in an adjacent water-course which yield more information respecting the continuity of the seam than could be hoped for from a further prosecution of the drift. As, therefore, there is no object in carrying the work on any longer, it is advisable to place on record the results obtained.

Friability of the coal.—With respect to the friability of the coal, no difference whatever is perceptible between coal taken from the fourth cross-cut and that at the actual outcrop. The former position is about 45 feet from the surface measured along the shortest line; a distance quite sufficient to prove that the friability is, as was anticipated, entirely due to crushing, and not in any degree to surface alteration. No hope can be entertained of obtaining coal from the Darjíling Damudas in anything but the powdery state already described.

Composition.—Neither is any difference discernible in the coal as to composition. In the following table assays are given of samples taken at various distances from the surface—

Distance from original outcrop along drift.	Distance from mouth of drift.	Distance from nearest point of surface.	Fixed carbon.	Volatile matter.	Ash.
0	...	0	66·3	12·4	21·3
10	0	?	66·8	11·4	21·8
20	10	7	67·5	14·4	18·1
30	20	15	64·4	10·4	25·2
70	60	40	63·8	12·5	23·7

Continuity of the seam.—The section of the seam at the outcrop is as follows (ascending):—

	Ft.	In.
(*a*)—Yellowish (slightly rusty) sandstone, seen about	12	0
(*b*, *d*)—Brown shale...	6	0
(*e*)—*Coal*	11	0
(*g*)—Sandstone, similar to (*a*), seen	8	0

The shale (*b*, *d*) is only partially exposed, and may include the layer of coal (*c*) visible elsewhere. The dip of the main seam here is west-15°-north at 80°.

In the first cross-cut there is only 5 feet 6 inches of coal, with sandstone on *both* sides of it, the shale (*b*, *d*), and the lower part of the seam, being evidently cut out by a small slip. The dip is badly seen, but appears to be about north-west at 70°.

At the second cross-cut, 6 feet 6 inches of coal is exposed, but the seam has not been cut through on the left side.

In the third cross-cut it is 7 feet 6 inches thick with shale below it. Dip seems to be about west-40°-north at 80°.

In the fourth, 10 feet of coal is exposed in the main seam, which is not cut through to the right. The dip appears to be the same as in the last cross-cut. There is a thin bed of coal included in the brown shale below.

The fifth cross-cut is entirely in shale, beyond which, at the end of the drift, is the sandstone *(a)*.

About 80 feet south-west of the fourth cross-cut the seam is exposed in a surface outcrop. It has a thickness of not less than 10 feet, and dips about south-20°-east at 30°. I do not think that this is the true dip, however, but merely a bending over of the seam at the outcrop caused by a slip of the surface debris, &c.

Thirty yards further the following section is exposed—

		Ft.	In.
(a)—Sandstone, seen	. ...	10	0
(b)—Brown shale	... ...	1	0
(c)—*Coal*	... ...	1	0
(d)—Brown shale	... ...	3	0
(e)—*Coal*	.. ..	12	6
(f)—Brown shale	... ...	0	9
(g)—Sandstone, seen	... ...	8	0

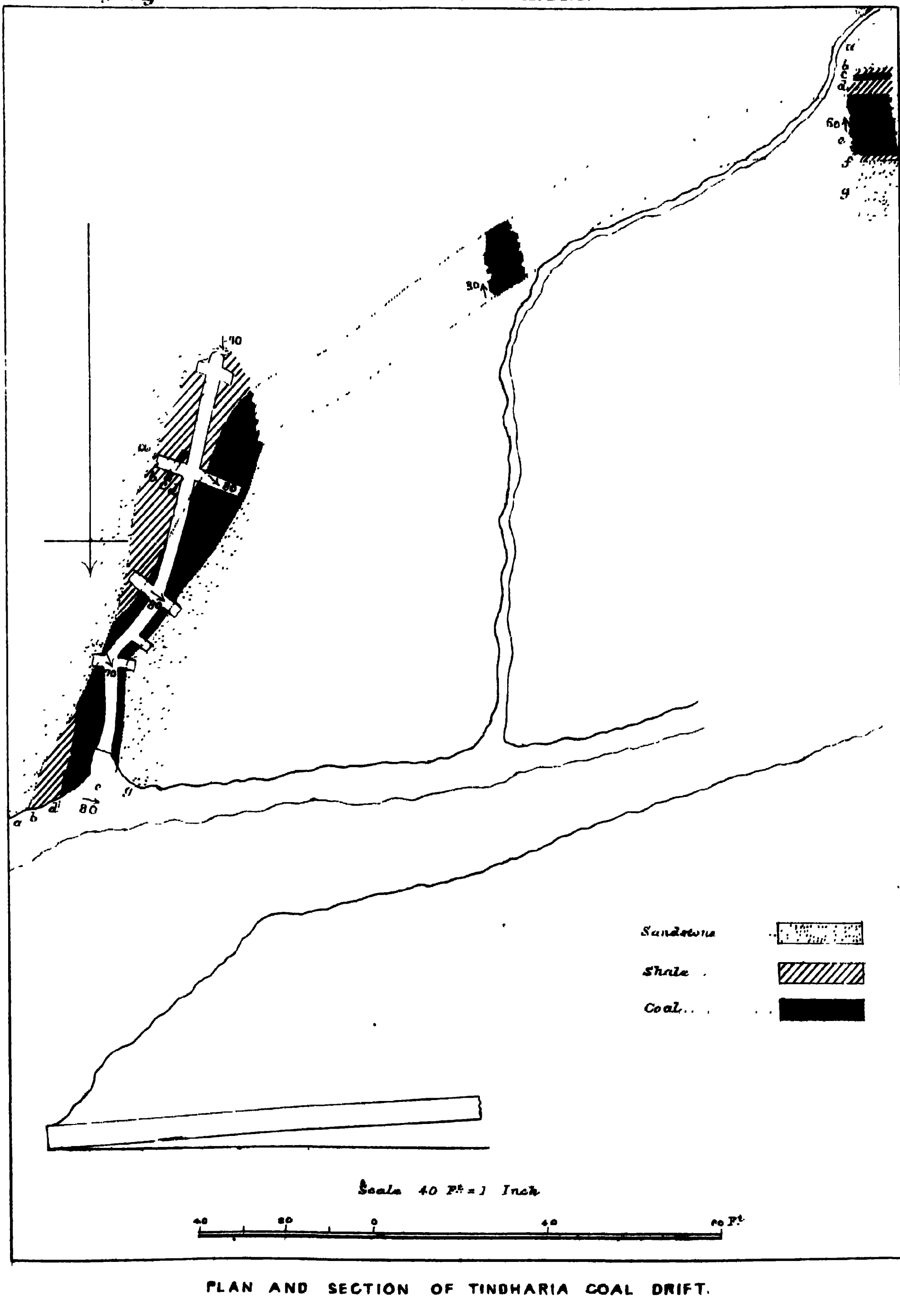
Dip about south at 60.°

Throughout, then, the length of 250 feet in which the seam is traceable, it possesses a fair degree of uniformity in thickness. But the strike twists round from south-15°-west to west, or through 75°; while the dip, which is 80° at one end, is an *inverted* one of 60° at the other, the difference being 40.° Of course these are merely local features affecting one portion of one seam, but my experience of the rocks generally does not lead me to suppose that the beds at Tindhária are subject to any unusual degree of distortion. Taking into account, then, that the Tindhária seam is thicker, and perhaps more uniform in thickness, than any yet found, it is manifest what extreme difficulty the condition of the rocks in question must oppose to any attempt at mining the coal seams generally.

Necessity for timbering.—The experience gained shows also that galleries cannot be driven into the coal for a single yard without complete timbering; on which, owing to the incoherent, non-self-supporting character of the coal, an unusually heavy pressure is put (which is shown by 'creep' of the floor of the gallery as well as by bulging in of the sides and roof); and owing to the heat and damp within the drift, the wood quickly becomes unserviceable from rot. With the comparatively trifling superincumbent weight of 40 or 50 feet of rock, some of the 3-inch planks were beginning to yield at the time of my visit; and Mr. Tyndall informed me that it was frequently necessary to renew them here and there, while a complete renewal would be necessary if it were decided to carry the work on further. No doubt the timber would last longer in a regular mine with an organized system of ventilation; but making every allowance for this, it is certain that the expense for timbering in any mines in the Darjíling coal would be extremely heavy.

Fire-damp.—It has also been shown that the coal is not altogether free from fire-damp, two slight explosions having occurred during the progress of the drift. There would be little to fear, however, on this score in regular mining operations, as the usual amount of ventilation would doubtless be more than sufficient to carry off the small amount of gas generated.

Coking properties of coal.—Some time ago a quantity of the coal was sent by Mr. Tyndall to Calcutta, and through the courtesy of Mr. Blackburn, Manager of the Oriental Gas Company's works, Mr. Medlicott and myself were enabled to experiment on its coking properties, in some gas retorts placed at our disposal.



PLAN AND SECTION OF TINDHARIA COAL DRIFT.

About 3½ cwt. of coal in its natural state, *i. e.*, in coarse powder and fragile lumps, was introduced into a retort, which was already at a red heat. The charge was kept at this temperature by means of an external furnace, for five hours, and then drawn. The coal came out in powder just as it went in. It lost its volatile matter, of course, but did not cake in the slightest degree.

Three and a half cwt. of coal, previously saturated with water, was treated in the same way for seventeen hours. The result was the same as in the last experiment.

In a subsequent series of experiments I sought to determine, as far as can be done on a small scale, what proportion of pitch added to the coal was required to give the coke a sufficient degree of firmness. Two pounds of the coal powder, passed through a sieve, of 6 holes to the inch linear, were intimately mixed with different proportions of coal-tar pitch (passed through a sieve of 20 holes to the inch linear), the mixture somewhat shaken down in the crucible, covered over with a thick layer of sand and the crucible lid, and then heated for an hour and a half. When withdrawn, the crucible had been for some time at a full red heat, and the evolution of gas had ceased. The results were as follow :—

	Proportions.	Quality of coke.
1	Coal 4 parts by weight Pitch 1 " "	Coke hard and firm.
2	Coal 8 parts by weight Pitch 1 " "	Coke of good quality, but less firm than No. 1.
3	Coal 12 parts by weight Pitch 1 " "	Coke fairly good; somewhat tender.
4	Coal 16 parts by weight Pitch 1 " "	Coke inferior; fragile.
5	Coal 32 parts by weight Pitch 1 " "	Coke very inferior; easily crumbled.

In a sixth experiment the coal was tightly rammed into the crucible without admixture of pitch. It coked to some extent, being about equal in that respect to No. 5.

It apppears, then, that the Tindhária coal will not coke at all when heated in a loose state, but that it will coke, although in a very inferior way, when previously compressed. It is also to be remarked that the Tindhária coal contains the largest proportion of combustible volatile matter (on the presence of which in sufficient quantity the coking mainly depends) of any Darjíling coal assayed, as shown in the following table.*

	Fixed carbon.	Volatile matter.	Ash.
Rakt naddi, 5′ 6″ seam	79·3	7·6	13·1
Cart road, 6′ 0″ seam	74·1	9·0	16·9
Chiraukhola naddi, 7′ 0″ seam	69·6	5·2	25·2
Tindhária ravine, 11′ 0″ seam	66·3	12·4	21·3
Ravine south of Pankabári, 0′ 9″ seam	64·0	11·8	24·2
AVERAGE	70·66	9·20	20·14

* Memoirs, G. S. I., Vol. XI, p. 54.

The failure, therefore, to produce good coke in the first experiments leaves little room to hope that such can be produced from any other Darjíling coal.

With respect to the production of coke with the aid of pitch, taking into account, on the one hand, that coke made on the large scale yields better results than in mere crucible experiments, and on the other that the Tindhária coal possesses a slight tendency to cake *per se*, which some other of the Darjíling coals do not, it may perhaps be inferred that about a tenth or twelfth of pitch, or say 2½ *mans* (maunds) to the ton of coal is about the smallest proportion which would be found to answer in practice. The price of coal-tar pitch at the present time in Calcutta being Rs. 2-4 a *man*, this quantity would cost over six rupees at Sukna—that is to say, the pitch alone would cost nearly half the amount at which Ráníganj coal could be delivered there per ton.*

The results of some experiments on a small scale, respecting the manufacture of patent fuel by agglutination with farinaceous matter, are mentioned in my report on Darjíling.† It yet remains to be proved, however, whether this plan would answer on a commercial scale. Attempts of this kind carried out at Ráníganj, with the object of utilizing the small coal of the collieries there,‡ were successful in the production of good fuel, but not at a paying rate.§

Conclusion.—Taking into account the extreme difficulty and corresponding expense which must be encountered in mining the Darjíling coal, and the subsequent expense of converting it into a usable form of fuel, I fear there is but little hope of working it at a rate less than, or even not exceeding, that at which Ráníganj coal could be laid down at the foot of the hills.

Assam coal.—In the coal of Assam, however, there is a supply which may eventually be found more advantageously available than either. If the projected communication should be established between the Názira coal-field and the Brahmaputra, and the branch line of the Northern Bengal Railway to Dubri be constructed, it is not improbable that coal taken down the Brahmaputra would command the market. Coke made from the strongly caking Assam coal mixed in due proportion with the anthacitic coal from Darjíling would probably be found (irrespective of cost) to yield a highly serviceable fuel, but the expense of manufacturing it would most probably be found greater than the cost of delivering the raw Assam coal at the foot of the Darjíling hills.

LIMESTONES IN THE NEIGHBOURHOOD OF BARÁKAR, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

NOT long ago, I had an opportunity of examining different deposits of limestone near the western border of the Ráníganj coal-field, which have acquired additional importance of late owing to their employment as flux at the Barákar iron-works. In visiting the different quarries that have been opened, I had, as guide, an intelligent native employe, who was kindly sent with me for the purpose by the Manager of the Company.

The most important localities—in fact the only ones in which limestone has been raised—are two, namely, Bághmára at the western end of Panchét Hill, and Hánsapathar, ten miles

* Memoirs, G. S. I., Vol. XI, p. 62.

† *Ibid*, p. 60.

‡ Records, Vol. VII, p. 162.

§ This fact in itself alone, however, cannot be taken as conclusive against the production of similar fuel in the Darjíling district. At Ráníganj, patent fuel must hold its own against round coal raised on the spot, whereas in the Darjíling district it would have the advantage of competing with round coal brought from long distances.

further west. The limestone in the former locality is of Damuda age, and was originally discovered by my colleague, Mr. Ball, in 1865, and mentioned in his progress report for that year. That at Hánsapathar is included in the gneiss. It was found in 1864-65 by Mr. W. L. Willson during his survey of the crystalline rocks.

Bághmára limestone.--Immediately east of the fault which brings the gneiss against the coal-bearing series at Bághmára* there is a north and south ridge composed of Rániganj sandstone, dipping to the east at an angle of 30 or 40 degrees. It is in the valley to the south of the village, between this ridge and Panchét Hill, that the outcrop where the quarries have been opened is situated. At the time of my visit three quarries had been opened in a line running N. N. E.—S. S. W., the distance between the two furthest apart being some 300 yards. The general section is not as clearly visible as might be wished, but, gleaned from the different exposures of rock, appears to be as follows (descending)—

(*d*).—Sandstone.
(*c*).—Arenaceous limestone.
(*b*).—Shaly red micaceous sandstone.
(*a*).—Limestone.

There is sandstone above the limestone (*c*), but it is not seen in immediate superposition, and there may be other beds between. The upper limestone, as seen in the most southerly quarry, is about 18 feet thick, and is repeated by a small slip. It is very massively bedded, but on the weathered surfaces traces of false bedding can be detected. The dip is east-20°-south at about 20°. The rock is of a dark greyish color and very arenaceous, with scales of mica and occasional bits of carbonized stems, &c.: the fracture is rough and uneven.

The limestone in the second (middle) quarry resembles that in the first. One hundred yards or so to north-west of it there is another outcrop, exposing a few feet of similar rock. Whether this is the same band faulted, or a distinct one lower in the section than (*a*), is not clear, as the intervening ground is covered with surface soil.

A little to one side of the third (most northerly) quarry the arenaceous limestone is partially visible, with a few yards of shaly micaceous sandstone below it resting on the limestone (*a*), which is exposed in the quarry itself. The last-mentioned rock is massively bedded, like the arenaceous band, and similar to it in color, but it is seen by the eye alone to be of a purer kind. The sandy element is much more subordinate, and the fracture is smoother and imperfectly conchoidal. Eleven or twelve feet of limestone is exposed in the quarry, but the bottom has not been reached. Dip east-30°-south at 15°.

I have recently made some analyses of average samples from each band, which give the following results :—

Upper limestone (c).

Calcic carbonate	45·05
Magnesic carbonate	11·53
Ferrous carbonate	3·64
Ferric oxide	·28
Phosphoric acid	·07
Insoluble (chiefly sand, but also includes scales of mica, with some clay and a small quantity of carbonaceous matter) ...	39·28
	99·85

* *Vide* Map of the Ránigauj Field: Memoirs, Geological Survey of India, Vol. III, Pt. 1.

The residue insoluble in acid contained 84·70 per cent. of silica, equal to 33·27 per cent., or just one-third the total weight, of the limestone.

Lower limestone (a).

Calcic carbonate	63·40
Magnesic carbonate	14·41
Ferrous carbonate	4·15
Ferric oxide	·62
Phosphoric acid	·12
Insoluble (sand with clay)	19·28
	101·98

Neither limestone contains more than a trace of sulphur. Of the insoluble residue in (*a*), 84·85 per cent., or 16·36 per cent. of the limestone, was silica. It will be seen that the upper band contains double as much insoluble matter as the lower. Exclusive of this, which s mainly mechanically mixed sand, the two limestones have very nearly the same composition.

	Upper band.	Lower band.
Calcic carbonate	74·26	78·17
Magnesic carbonate	19·01	17·76
Ferrous carbonate	6·00	5·13
Ferric oxide	·46	·77
Phosphoric acid	·12	·15
	99·85	101·98

The inferiority of the upper band has been already proved by experience, and the working of it has been abandoned for some time. The only quarry now open is in the lower band, which, as may be seen from the analysis, is of fairly good composition, although containing an undesirably large percentage of silicious matter.

The quantity of lime that may be expected from it is tolerably large. In the present quarry the band has a *minimum* thickness of 11 or 12 feet, and it can probably be advantageously followed for some hundred yards along the outcrop. The average dip of 15° or 20°, however, with rising ground to the east, would not allow of its being quarried far in the direction of the inclination of the beds.

Besides its employment as flux, this stone has been burned for lime to some extent at Narrainpur, where coal is raised, and at Barákar. The distance from the quarry to Barákar is about 10 miles, by a good *kacha* road as far as the Damuda, and over a metalled road for the remainder of the way.

The calcareous horizon may be traced in a north-easterly direction from Bághmára to near the Damuda, west of Narrainpur. But in this northern portion of the outcrop the bands are more earthy and impure than the lower one, at least, at Panchét Hill. There appear to be three or four bands, which are all thin and arenaceous. The sandstone, also, contains calcareous nodules. It would seem as if the deposition of earthy and sandy material has been greater to the north than at Panchét Hill, and that the calcareous element has been more 'diluted' as it were.

A little south of the boundary between the Ironstone Shales and Rániganj group, at the villages of Jassaidhi and Gangutia (about two miles south-east of Barákar), a band of limestone is visible which seems to belong to the same horizon. It is only a few feet thick, and gave on assay 38·2 per cent. of insoluble matter; so that it is useless as a source of lime.

It appears from the foregoing details that the calcareous bands are in the Rániganj group, at the lower part of it. The contiguity of the Panchét beds to the limestone, south of Bághmára, is therefore apparently due either to the unconformity between the Rániganj and Panchét groups,* or to an undetected fault to the east of the limestone.

Hánsapathar limestone.—Six miles west of Bághmára there is an abundant supply of limestone of good quality, occurring as a strong band in the gneiss. The country is open, with merely a thin covering of soil, through which the rock penetrates in many places.

In a quarry half a mile west of Hánsapathar the outcrop is some 50 yards broad, the beds having an average dip of 30° to the north, giving a thickness of rock of 70 or 80 feet. Of this, I think, fully three-fourths are available limestone, the remainder consisting of inferior stone, and perhaps intercalated beds of gneiss. The quarry is near the bank of a small stream, and elevated 10 or 15 feet above it; so that there is a large quantity of stone above the water-level. A little to the east, the dip (either by a very sharp twist, or by a fault) alters to east, and is nearly vertical. A short way north of Hánsapathar some 25 feet of limestone is seen in another quarry, but this is only a portion of the whole. On the north side of Asta, again, the rock occurs in great force, dipping to the north at 50°—80°. The breadth of the outcrop is about 60 yards, giving a thickness of, say, 150 feet, of which more than three-fourths is seen to be good stone, free from bands of gneiss, &c. The amount of free drainage here is about the same as in the quarry first mentioned. The limestone is also exposed, although less fully, half a mile east of Asta.

Considering, then, that the outcrop is *visible* for about two miles, and the thickness of the band, it is clear that the amount of stone within reach is very large indeed, while the thinness of the superincumbent soil, and the circumstances of the drainage, allow of its being worked under very favorable circumstances.

The rock is a white crystalline limestone, which varies somewhat in texture. Some parts are comparatively fine-grained; in others the crystalline facets are a tenth of an inch in diameter. Some beds contain strings and nests of quartz and felspar, and disseminated crystals of actinolite. When such impurities occur in large quantity, the beds containing them weather more slowly than the others, and stand out more prominently above the surface. Scales of brown mica (phlogopite?) are frequently scattered through the rock.

The analysis of an average sample of this limestone yielded—

Calcic carbonate	83·43
Magnesic carbonate	·78
Ferrous carbonate	·68
Phosphoric acid	·02
Insoluble	16·18
	101·09

Of the insoluble residue, 80·35 per cent. (or 13·00 per cent. of the limestone) is silica. The rock only contains a trace of sulphur (less than ·01 per cent.)

* *Vide* Memoirs, Geological Survey of India, Vol. III, page 126.

The superiority of the Hánsapathar rock to the lower band at Panchét Hill is therefore less marked, with respect to the amount of insoluble impurity it contains, than might be expected from its outward appearance. A large proportion of this impurity consists of white, translucent, silicious grains, which are not easily detected by eye in the similarly coloured stone. But while the Panchét rock contains some 15 per cent. of carbonate of magnesia, the Hánsapathar contains scarcely any, being, with the exception of the insoluble matter, almost pure carbonate of lime. It contains 20 per cent. more carbonate of lime than the Panchét stone, and less phosphoric acid.

Hence, both for use as a flux and as a source of lime, the Hánsapathar rock is markedly superior. But it is also well worth attention as a marble. In texture, colour, and uniformity, it is, I think, equal to the average of the Rájputána marble, which is so well known from its employment in the Táj Mahál at Agra, and other monuments in the North-Western Provinces. Many of the beds are several feet thick—some as much as six or eight; so that blocks of any required size could be extracted.

By the present route, *viâ* Bághmára and Narrainpur, the distance from Hánsapathar to Barákar is about fifteen miles, of which eleven is over a *kacha* road, and the remainder over a metalled one. In a straight line, however, it is only twelve, and a direct *kacha* road, easily passable by country carts, could be made at a trifling expense.

Crystalline limestone has also been found at Rámpur and Bhargora by Mr. Ball, and by Mr. Willson at Moháda and east of the village on the bank of the Otla naddi. These places are all a mile or two west of Panchét Hill. In none of them, however, can the rock compare with that of Hánsapathar. The Rámpur stone is the best, but even there the proportion of good stone is comparatively small.

In addition to the two principal localities where limestone occurs, given above by Mr. Mallet, and which were both mentioned by me in an unpublished account of the district of Manbhum, it may be of interest to record the existence of some others in that district. The most important is situated on the main bounding fault of the coal-field, close to the village of Jamuan, about five miles to the south-west of Raniganj and nine miles south-east of Assunsole. There is no specimen of this rock at present available for examination, but when seen, it was noted as being apparently a tolerably pure limestone. As to its abundance, that can only be determined by opening up the ground at the time of its discovery, but a small quantity was visible.

In the other localities the rock is magnesian (dolomitic), and as such unsuited for a flux, but may prove useful for other purposes. One of these localities is situated on the east of the village of Ramlallpur, two miles south of the above given position. The other is on the faulted junction of the crystalline and sub-metamorphic rocks close to the spot where copper ores* occur near one mile north-east of Purda, Pergunnah Manbazaar, and thirty miles east-south-east from Purulia.—*J. Ball.*

ON SOME FORMS OF BLOWING-MACHINE USED BY THE SMITHS OF UPPER ASSAM, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

THE smelting of iron, which at one time was an important industry in Upper Assam, more especially along the skirts of the Nágá Hills,† has been extinct for many years. But although the Assamese, in that part of the province at least, have ceased to produce iron themselves from the ore, there is still a not inconsiderable demand for manufactured articles, *dhaus* and spears for barter with the Nágás holding a prominent place amongst such. The materials used now, however, are mainly English iron and steel, which, from their cheapness and the convenient forms in which they are to be had, have driven the native product out of the market.

As the contrivances used by the smiths of Upper Assam are essentially different from those met with in India proper (Peninsular India), the following descriptions may not be

* *Vide* Records, 1870, p. 76.

† Memoirs, Geological Survey of India, Vol. XII, p. 360.

without interest. In India, although the forms of apparatus vary greatly in different parts of the country, they are, I believe, all modifications of the bellows, the supply of air depending on the alternate expansion and contraction of one or a pair of vessels constructed, wholly or in part, of a flexible material, like leather or raw skin. The contrivances used in Upper Assam are blowing cylinders, made of rigid material. Some machines have a double-acting single cylinder; others, a pair of single-acting cylinders. The first of these is the form most commonly used, and may, therefore, be given precedence.

The cylinder (*aa*, plate I), about 3 feet long by 10 inches diameter and three-fourths of an inch thick, is cut out of a solid piece of wood; the excavation of the interior, as well as the shaping of the outside, being done with the ordinary simple tools possessed by the villagers. I have never seen any cylinders which had been turned or bored. Into the ends, disks of wood are fitted by rough dove-tailing (*bb*), the circular joints between disks and cylinder being rendered air-tight with clay. In the centre of one disk is a small hole in which the piston-rod (*c*) works. The latter is generally made from a slip of bamboo split from a large-sized piece, and has a diameter of, perhaps, three-eighths of an inch. At one end is a cross-handle (*d*); at the other, the piston (*e*): this is a disk of wood somewhat smaller in diameter than the cylinder and having a groove cut in the circumference, into which strips of skin from the necks of cocks are sewn by twine passing through holes for the purpose in the edge of the piston. The long, soft feathers fill up the space between the piston and cylinder, and produce but little friction, while not allowing much air to pass through. Rags are also sometimes used for this purpose, but are less effective. In both the end disks there is a double orifice (*f*) fitted with a valve (*g*) opening inwards; the latter made of leather, or a couple of folds of stout paper, fastened at one side by a slip of wood nailed to the disk. The object of the orifice being double is, that the division in the middle may give support to the valve, and prevent it being forced out by the presence of the air when the piston is approaching it.

Close to each end of the cylinder there is a hole (*h*) of an inch or so in diameter, which allows the air to pass into the tubes (*ii*). These are semicircular channels, cut in a piece of wood (*j*) of nearly the same length as the cylinder, to the side of which it is nailed. As the channels approach each other, they bend round and end in circular orifices (*k*), into which are fixed two bamboo blast-pipes (*l*), approaching each other at an angle of about 20 degrees. These reach some way into the tuyere (*m*), which penetrates a clay screen (*n*), the use of which is to protect the blowing-machine from the heat of the charcoal fire (*o*). The cylinder is generally supported on a couple of pieces of wood (*p*), so as to give the blast-pipes sufficient downward inclination. It is securely fixed by a stake (*q*) at each end driven into the ground.

In using the machine, a man sits on the ground, and grasping the handle (*d*), works the piston backwards and forwards with a stroke of about two feet. When pulling, the valve (g^1) opens and admits air into the cylinder, while (g^2) shuts, so that the entire blast is driven through the pipe (l^2). In pushing, the action is, of course, reversed. The two defects of the machine are, that at the end of each stroke there is a momentary cessation of blast, and that a certain proportion of the air drawn into the cylinder is supplied by a return draft through the pipe (l^1), which somewhat diminishes the force of the blast into the fire from (l^2). The former defect could be remedied by adding an air-chamber, of sufficient capacity to steady the blast, between the pipes (*l*) and the screen, one pipe of larger diameter than (*l*) projecting from the air-chamber into the tuyere. The latter defect could be obviated by closing the holes (*h*) or the pipes (*l*) with valves opening outwards.* In practice, however, neither defect is of much consequence, as the machine, as it stands, answers the

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* This defect, and its remedy, has been already pointed out by Mr. Medlicott.—*Memoirs, Geological Survey of India, Vol. IV, p.* 413.

purpose for which it is intended, and gives as strong a blast as is required by the smiths, at the cost of a slight amount of extra labour.

The double-cylinder machine, represented in plate II, was observed at Burhât on the Disáng. Two wooden cylinders (*aa*), about 2 feet 6 inches high and 7 inches external diameter, are placed close to each other, and secured by being tied to two stakes (*bb*) driven into the ground (*cc* represent the fastenings). The upper ends of the cylinders are open, while there is a hole (*d*) about an inch diameter in the side of each, near the bottom. The pistons are similar to that in the last machine, except that there are no handles at top of the rods.

The man who works the machine stands behind it, holding the end of one piston rod in each hand, and working them up and down alternately, one being pushed down, while the other is being pulled up. This machine has the same defects as the first mentioned. As there is only one orifice into each cylinder, the entire indraught would pass through the blast pipe (e^2), and greatly diminish the blast into the fire, if the pipes were fixed to the body of the machine. But a space of an inch or so is left between the ends of the pipes and the cylinders. Through it the indraught (d^2) mainly takes place, while the force of the direct blast (d^1) is not materially diminished.

In the Nágá village of Rangkatu (11 miles south-east of Mákum) I observed an ingenious modification of this blower, constructed entirely out of bamboo. The cylinders (plate III) were each formed out of one segment about five inches diameter, with a portion of a second segment left below the joint, to allow of the whole being firmly planted in the ground. Between the cylinders, which were about a foot apart, an upright was fixed, with a cross-piece tied to it near the top. To this cross-piece the piston rods were fastened, while at the extreme end was a string held by the smith. The piston remote from him being weighted with stones (*aa*), a continuous action was kept up by the smith alternately pulling the string down and allowing it to rise. This machine, although from its smaller size is less powerful than the second one, has an advantage over it in that it can be worked by the smith himself sitting over his fire, without the aid of an assistant.

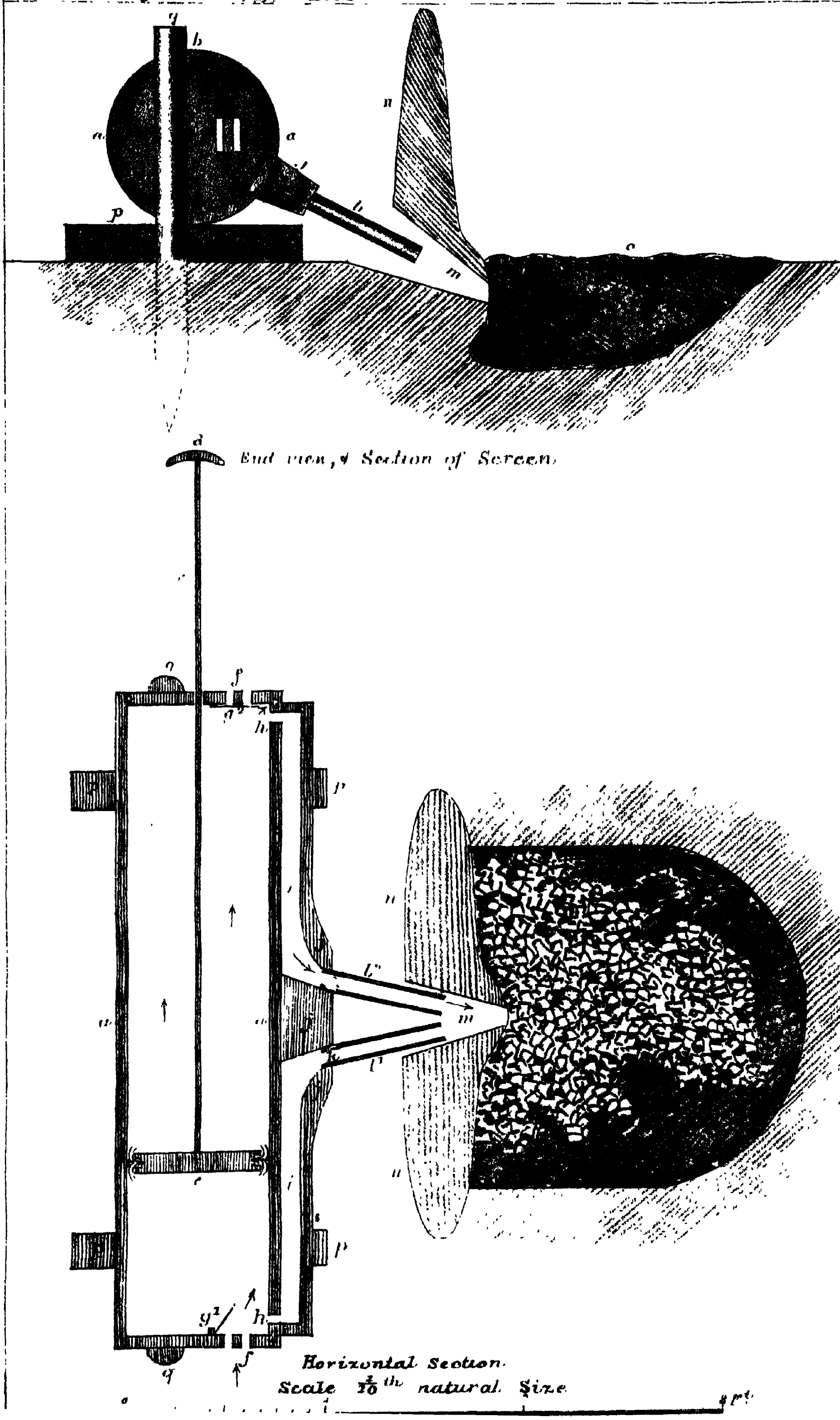
Although, as far as I am aware, blowing cylinders are not used in any part of Peninsular India, they have been found amongst widely-separated communities elsewhere. I am informed by Mr. W. Theobald that a pair of single-acting cylinders, similar to the second machine mentioned above, is commonly used in Mártabán and east of the Sittáng, as well as, probably, in other parts of Burma. The same machine, but of larger dimensions, is also used in Borneo. The cylinder is "made of the stem of a tree hollowed out, about 5 feet 6 inches high and 3 feet in circumference."* The natives on the north coast of New Guinea use a machine made, like that at Rangkatu, out of two large joints of bamboo. "This instrument is identical with the bellows in use amongst the brown races of the Archipelago, from whom it may have been borrowed."† A machine, resembling the Borneo one, is made use of by the natives of Madagascar,‡ who, it appears, may have derived their knowledge of it from Malay sources; and it appears that wooden blowing-machines are common amongst the Chinese,§ from whom, or from the Burmese, it is probable that the Assamese have acquired a knowledge of the principle.

* Percy.—Metallurgy of Iron and Steel, p. 274.

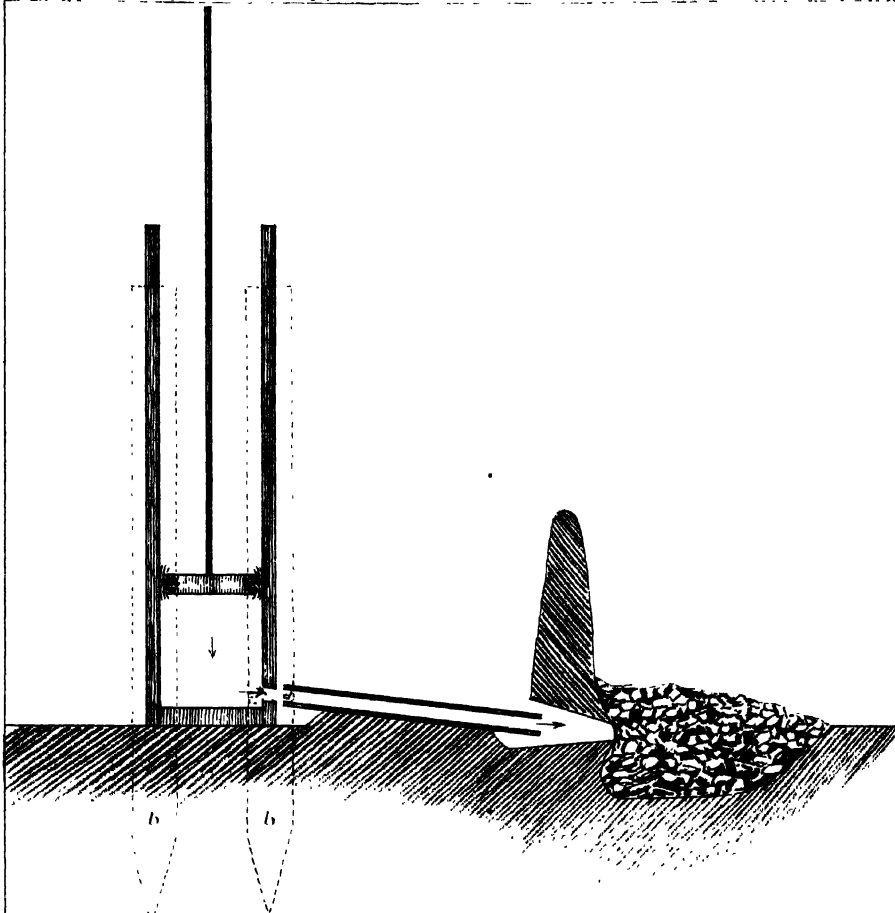
† The native races of the Indian Archipelago, Papuans, by G. W. Earl, M.R.A.S.—Ethnographical Library, Vol. I, p. 76.

‡ Percy.—Metallurgy of Iron and Steel, p. 277.

§ *Ibid*, p. 274.



Horizontal Section.
Scale 1/10 th natural Size



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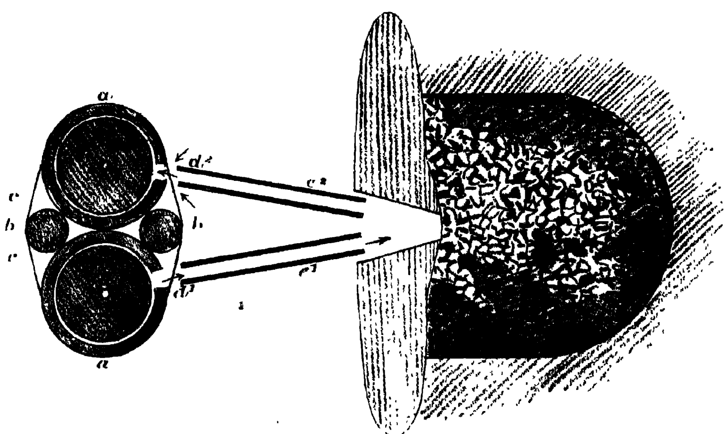

Horizontal Section

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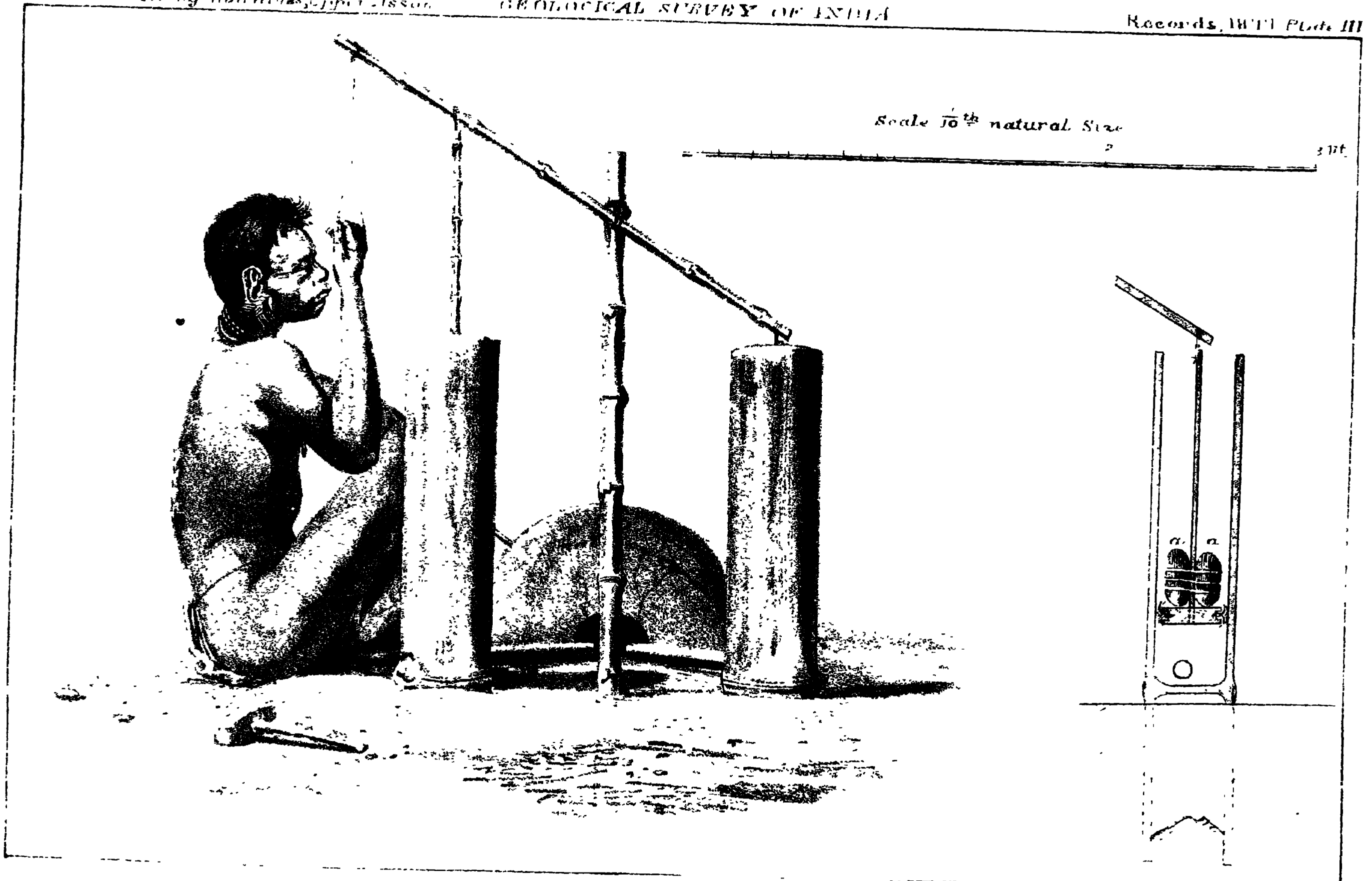
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ANALYSES OF RÁNIGANJ COALS, *by* A. TWEEN, *late of the Geological Survey of India.*

The analyses recorded in the following tables were made in the laboratory of the Geological Survey during the years 1870 to 1873. This detailed examination of Indian coals was undertaken by Dr. Oldham, then Superintendent of the Survey, in conjunction with Colonel Hyde, R. E., then Master of the Mint. A quantity of coal (about four tons) was sent by the leading coal companies from each of their principal pits. A large steam engine was set apart at the Mint, carefully fitted with instruments for recording the conditions of the experiments throughout, for the direct trial of these wholesale samples, each trial extending over several days. Portions of each coal were put aside at intervals during the feeding of the furnace, so as to ensure a fair average; and this was sent to the laboratory for analysis. Thus, as to sampling, which is so important a matter in the case of analyses, when so very small a proportion is actually submitted to examination, it would seem that every precaution was taken to ensure a safe result.

The trials at the Mint were of so tedious a nature, not only in execution but also as involving a mass of complicated calculations, that there was necessarily much delay in preparing the results, and the publication of the analyses was postponed that all might appear together. As these chemical results are, however, quite intelligible by themselves, and have a value quite independent of the other method of trial, it seems a pity not to give them to the public. They are, indeed, much the more accurate and absolute results of the two, being quite free from the many sources of error that beset the grosser method of experiment. The one doubt that affects the analytical method is that of correct sampling, and, as has been said, every care was taken to ensure safety on this score. Some results of the practical experiments have been obligingly placed at our disposal by the Master of the Mint; but unless accompanied by an account of the process of experiment and of calculation, the information would not be complete. For a like reason we do not publish some tests of the same coals kindly furnished by Professor Pedler, who, at Colonel Hyde's request, had measured the evaporating power by Thompson's calorimeter. Only one small fragment (about two or three cubic inches) of each coal was sent for this experiment, so the results could scarcely be taken as representative.

The chemical examination was conducted in the following manner:—Several samples of each coal were sent, corresponding to the number of days of trial at the Mint. These were mixed together and broken up into small fragments, avoiding dust as much as possible. A portion was reserved, from which the analyses were made, and the specific gravity taken. The remainder was burnt in the following manner:—A small portion was first placed upon an open grate and the smokeless flame of a gas burner (over wire-gauze) placed underneath. When this was well kindled, the larger quantity was added, and a chimney placed on top; a very perfect combustion was the result, the ash, before being disturbed, retaining the shape of the fragments of coal, and scarcely a particle falling through the grate.

Two hundred grains of each coal were kept at a temperature of 212° for about four hours for determining moisture; 50 grains were gradually heated in a closed crucible to bright redness for the volatile constituents and coke; 100 grains were burnt in a platinum capsule for estimating the ash. The carbon and hydrogen in the dried coal were estimated by combustion with oxide of copper in oxygen gas, and the sulphur by fusing with nitre, carbonate of soda, and common salt. For the analysis of the ash, 50 grains of the larger quantity burnt were taken. This was fused in two portions with the ordinary fusing mixture. The acid solution of one portion, after removal of silica, was divided for the estimation of the sulphuric acid and phosphoric acid. The remaining constituents were determined from the other portion. A separate portion of each ash was examined for alkali by digestion with water, but no more than a trace was found in any.

No. of sample.	Name of colliery.	Specific gravity.	Percentage of coke in the undried coal.	Ordinary Assay.					Combustion with	
				Moisture.	Volatile, (combustible).	Carbon, (fixed).	Ash.	Total.	Carbon.	Hydrogen.
1	2	3	4	5	6	7	8	9	10	11
1	Bábúsól (B.C.C.) ...	1·378	65·8	6·8	27·4	52·1	13·7	100	68·20	5·04
2	Maddápúr (B.C.C.) ...	1·366	65·8	6·6	27·6	52·4	13·4	100	68·36	4·99
3	Mangalpúr (B.C.C.) ...	1·370	67·8	5·8	26·4	55·1	12·7	100	68·91	4·80
4	Ráníganj (B.C.C.) ...	1·318	64·6	6·2	29·2	49·6	15·0	100	66·40	4·89
5	Ditto (B.C.C.) ...	1·360	66·0	6·7	27·3	53·9	12·1	100	67·77	4·79
6	Ditto (B.C.C.)	1·355	65·4	6·2	28·4	53·1	12·3	100	66·81	4·86
7	Nimcha (B.C.C.) ...	1·422	69·0	5·4	25·6	51·1	17·9	100	63·94	4·60
8	Beldánga (B.C.C.) ...	1·458	66·6	5·2	28·2	48·4	18·2	100	64·28	4·48
9	Chinákúrí (B.C.C.) ...	1·370	67·4	4·5	28·1	54·4	13·0	100	66·12	4·68
10	Purriapur (B.C.C.) ...	1·412	70·5	3·8	25·7	51·5	19·0	100	63·07	4·60
11	Dúmakúnda (B.C.C.) ...	1·368	76·8	2·0	21·2	63·4	13·4	100	71·86	4·67
12	Sanktoria (B.C.C.) ...	1·343	74·6	2·2	23·2	61·4	13·2	100	68·89	4·52
13	Mangalpur (N.B.C.) ...	1·406	70·2	4·7	25·1	54·6	15·6	100	66·83	4·74
14	Dhadka (N.B C.) ..	1·414	73·8	4·0	22·3	55·7	18·0	100	63·04	4·54
15	Banali (N.B.C.) ...	1·369	69·4	4·2	26·4	55·3	14·1	100	69·98	4·79
16	Mangalpur (N.B.C.) ..	1·389	68·6	6·4	25·0	53·4	15·2	100	65·38	4·71
17	Belrúi (N.B.C.) ...	1·386	71·0	3·0	26·0	55·3	15·7	100	69·12	4·96
18	Ragunath Bally (N.B.C.)	1·412	73·5	3·4	23·1	54·7	18·8	100	66·03	4·50
19	Fathépúr (A.) ..	1·462	70·0	4·2	25·8	45·3	24·7	100	58·21	4·32
20	Sitárámpúr (A.) ...	1·379	69·2	2·4	28·4	52·2	17·0	100	66·43	4·77
21	Mohanpúr (A.) ...	1·456	71·6	1·0	17·4	58·6	23·0	100	66·65	3·46
22	Charanpúr (A.) ...	1·375	66·6	4·8	28·6	52·0	14·6	100	65·80	4·64
23	Bénódákatta (?) ...	1·418	80·0	1·2	18·8	62·7	17·3	100	73·39	4·01
24	Dhasal—Chaukidanga (E.C.C.) ...	1·352	65·4	5·9	28·7	52·8	12·6	100	67·38	5·06
25	Charakdanga (E.C.C.) ...	1·385	69·0	5·4	25·6	54·5	14·5	100	67·63	4·79
26	Mangalpúr (R.C.A.) ...	1·400	67·2	6·5	26·3	51·2	16·0	100	64·49	4·64
27	Púránadip (R.C.A.) ...	1·501	69·2	6·5	24·3	45·5	23·7	100	57·09	4·47
28	Dhasal (R.C.A.) ...	1·384	66·4	5·8	27·8	51·0	15·4	100	67·22	4·71
29	Topasi (R.C. A.) ...	1·395	67·0	6·2	26·8	51·0	16·0	100	65·38	4·72
30	Ditto (R.C.A.) ...	1·407	66·0	7·0	27·0	48·4	17·6	100	64·02	4·55
31	Nigiah (R.C.A.) ...	1·394	65·8	5·0	29·2	48·2	17·6	100	63·77	4·62
	Averages ...	1·393	69·0	4·8	25·83	53·2	16·17	100	66·2	4·64

B. C. C.—Bengal Coal Company.
N. B. C.—New Birbhúm Company.
A.—Messrs. Apcar and Co.

Oxide of Copper in Oxygen.				Composition of the Ash.								
Oxygen and Nitrogen.	Sulphur.	Ash.	Total.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Sulphuric Acid.	Phosphoric Acid.	Total.	No. of sample.
12	13	14	15	16	17	18	19	20	21	22	23	24
10·66	1·10	15·0	100	60·40	23·67	8·25	2·47	3·37	·35	1·31	99·82	1
11·33	·82	14·5	100	52·92	33·48	6·60	2·30	1·27	1·20	·66	98·43	2
12·11	·88	13·3	100	59·66	26·72	8·08	2·92	...	1·00	1·18	99·56	3
11·35	1·30	16·0	100	60·24	28·30	7·04	1·80	·42	1·00	·78	99·58	4
13·58	·86	13·0	100	57·00	25·46	9·60	3·28	·94	1·30	1·03	98·61	5
14·27	·96	13·1	100	58·04	26·47	9·17	3·38	·30	·80	1·50	99·66	6
11·56	1·00	18·9	100	57·50	25·52	11·20	3·67	·51	·50	2·00	100·90	7
11·18	·86	19·2	100	46·04	16·20	31·06	3·96	1·40	·50	1·77	100·93	8
13·97	1·23	14·0	100	62·68	22·88	8·32	1·82	1·12	·85	·74	98·41	9
11·88	·75	19·7	100	62·50	24·32	9·64	2·13	1·21	..	·33	100·13	10
8·78	·69	14·0	100	60·54	31·00	6·52	1·21	·94	·55	·54	101·30	11
12·27	·82	13·5	100	58·00	29·03	7·49	3·26	...	1·11	1·46	100·35	12
11·15	·98	16·3	100	57·20	33·82	4·00	3·48	..	·50	1·10	100·11	13
13·02	·40	19·0	100	64·02	29·22	3·62	1·54	·81	·55	...	99·76	14
10·06	·37	14·8	100	62·77	30·48	3·32	3·18	..	·47	1·20	101·42	15
12·66	·55	16·7	100	57·52	32·04	4·47	4·63	.	·45	1·65	100·76	16
9·15	·57	16·2	100	62·66	29·21	3·80	2·55	·75	·48	1·11	100·86	17
9·38	·69	19·4	100	64·89	27·71	2·55	3·10	...	·40	1·05	100·30	18
11·13	·54	25·8	100	63·75	28·73	4·83	1·96	...	...	·64	99·91	19
10·58	·82	17·4	100	62·85	30·56	3·28	2·00	·55	·45	·75	100·44	20
5·49	1·20	23·2	100	73·00	26·26	...	·80	...	...	...	100·06	21
13·15	1·01	15·4	100	57·16	34·51	2·62	4·45	...	·50	1·10	100·34	22
4·35	·95	17·3	100	64·05	25·86	9·18	1·31	...	...	...	100·40	23
13·10	·96	13·5	100	61·75	32·70	2·90	2·51	...	...	·84	100·70	24
11·39	·79	15·4	100	58·00	32·54	4·00	4·21	...	...	1·46	100·21	25
12·97	·80	17·1	100	58·16	34·45	5·55	2·55	...	...	·40	101·11	26
12·51	1·63	24·3	100	63·16	26·46	6·16	2·88	...	·25	1·03	99·94	27
11·03	·74	16·3	100	64·14	30·37	2·11	2·94	...	...	·95	100·51	28
12·05	·85	17·0	100	62·00	28·11	4·41	3·97	...	...	1·02	99·51	29
11·77	·86	18·8	100	65·19	27·80	4·10	2·40	...	...	·20	99·69	30
12·61	·50	18·5	100	64·10	29·33	2·28	3·40	...	·53	1·00	100·64	31
11·30	·85	17·01	100	60·70	28·51	6·32	2·77	·43	·44	·83	100·00	

E. C. C.—Equitable Coal Company.
R. C. A.—Ránigunj Coal Association.

NOTE.—The 31 samples of coal furnished by the five great coal proprietors in the Ránigan coal-field, namely, the Bengal Coal Company, the Ránigan Coal Association, the Equitable Coal Company, the New Birbhúm Coal Company, and Messrs. Apcar and Co., represent fairly the quality of fuel which can be supplied from our oldest and most extensively worked coal-field.

The large quantity of ash is the feature that characterises our Indian coals, and to this circumstance is due their diminished vitality as contrasted with English coals. The proportion of oxygen, too, is a disadvantage, reducing the calorific power of the fuel; but I do not perceive that, as compared with the average of British coals, those of the Raniganj field show unfavourably. As regards sulphur, the Indian coals are on the whole more free from it than the English, the mean of—

37 Welsh samples being	... ... 1·42	Playfair and De la Beche's investigations.
8 Derbyshire „ „	... . 1·01	
28 Lancashire „ „	... ... 1·42	
17 Newcastle „ „	.. .. ·94	
8 Scotch „ „	... ... 1·45	

The excessive amount of ash is the chief defect of the coals raised in the Rániganj field, and I think it vain to expect that any deeper workings will effect any improvement in this respect.

A point of some interest, but which, unfortunately, the foregoing analyses bear upon but slightly, is the relative values of the coals from the upper and the lower measures. Out of all the samples there are only two from the lower measures—No. 11, Dúmákúnda pit coal, owned by the Bengal Coal Company, and No. 23, Benodákatta quarry coal, belonging to Messrs. Apcar and Co. The accident of distribution has rendered the beds of the upper measures most accessible, and it is amongst them that the greatest number of collieries have been opened out; hence there is a large preponderance of samples of the upper coals. The Dumákúndá and Benodákatta coals both appear to be of high heating power, and their theoretical fuel-value expressed in heat-units is as compared with carbon as follows:—

Carbon	8080° (Centigrade.)
Dúmákúndá	7040°
Bénódákatta	7023°

In none of the coals of the upper measures does the calorific power when theoretically calculated exceed that of these two samples; and though the above figures may not be accepted as the true gauge of the practical working value of these coals, I think they tend to show that the beds of the lower measures are worthy of attention. The ultimate analysis of these two coals indicates a higher percentage of carbon than in any others, and a less amount under the head of oxygen and nitrogen, both of which are important circumstances in their favour.

I have heard practical men express very conflicting opinions about both of these coals: each one was, probably, speaking according to his conviction; but with the evidence of the analyses before me, I am inclined to ask whether those who condemned the coals saw them fired under suitable conditions.

Of gas-coals, the best known is Sánktoria, which yields about 9,000 cubic feet per ton; the seam varies in quality along its strike, at Belrui there being a less percentage of permanent gases in the volatile matter than at Sánktoria. The analyses of these two samples from the same seam show for Sánktoria coal 25·4 per cent. of total volatile matter, and for Belrui 29 per cent, yet Sánktoria coal yields more cubic feet of gas per ton. I draw attention to this circumstance in order to illustrate the fact that comparisons between the total amounts of volatile matter are no guide to the relative gas-producing merits of coals.

T. W. H. HUGHES.

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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1877. [May.

NOTE ON THE ROCKS OF THE LOWER GODÁVARI, *by* W. KING, A. B., F. G. S., *Geological Survey of India.*

In the Madras Presidency my work of last season was carried on in the Godávari District, the Nizam's Dominions adjacent to this, and thence northwards by Sironcha and Maleri, over which latter country Mr. Hughes and I made a joint survey of some unsettled features in its geology.

In the Godávari District, as far as it is included in Sheet 94, the survey of all the more important formations has been completed; while the area of the crystalline rocks, though not examined in much detail, has been ascertained, and the inland boundaries of the great alluvial deposits of the Delta and thence along the coasts have been laid down.

In addition to the regular survey of the country, I was occupied for some time in directing the coal-borings at Beddadanole, which were carried on until the end of May, when the works were stopped by the coming on of the monsoon. Some delay was caused by the loss of boring rods and the unsuitability of the tools for greater depths than 350 feet; but sufficient exploration had been made to lead me to the conclusion that it was not advisable to continue the trials any longer. The trial borings were made over about one-third of the area of the field, sixteen holes were put down, from 193 to 356 feet in depth, and six seams of carbonaceous clays, clays with films of mineral-charcoal, and coaly shale were passed through. None of the coaly material met with was of any use as a fuel; and there were no indications of improvement in the seams as they were tested in their extension. From the floor of the field, which was struck on its eastern edge, to the highest exposed beds as they crop out from under the Kámthis on the western edge, there was no improvement in the seams as to their depth in the field. The line of bore-holes across the strike lead me to conclude that more than 600 feet of Barákars were pierced. On the other hand, the country of Kámthis to the westward, overlying any possibly hidden seam in the upper part of the Barákars, rises too rapidly to allow of search in that direction to moderate depths with any hope of success. On these grounds I sent in my final report to the Madras Government, advising that the explorations should be discontinued; and the order thereon has since been issued intimating that it is not necessary to continue the borings; but that it may be worth while having a shaft sunk to see the material of the best seam in some quantity. I am, on this, directed to advise the Executive Engineer in charge as to the site of such shaft in case of its being decided to excavate it.

In my rapid and rather devious march northwards from the Godávari District to the Central Provinces I was enabled to trace, on the western or Hannamconda side of the country in the Nizam's Dominions, the connexion of the Godávari Gondwánas with their equivalents around Sironcha, Kota and Maleri; while some further extension of the coal-measures was found to be probable to the north of the Kamárum coal field near Pakhál.

Much of my time during the early part of the season was occupied in going over old ground in the Godávari District, examining the details of groups of rocks, so that the area of country surveyed is not large; but in the traverse to the north a tolerably fair knowledge was obtained of the general character and relations of the rocks of a new area extending over about 2,000 square miles, or 1,590 square miles in Sheet 74, and in the Hyderabad Sheet 400 square miles.

The succession of groups of rocks in the Godávari District (Sheet 94) remains the same as has been already pointed out in my previous notes; but some alterations as to the extent of these and a revision of their boundaries have become necessary in consequence of my having found last year that the patch of sandstones (Golapilly) north-north-west of Ellore is mostly of the Rájmehál group, and not, as was at first considered, of Kámthi age.

The groups which I would now finally put forward for the different series in this district, and tentatively for those in the parts of the Nizam's Dominions and Central Provinces lately examined, are as follows, in descending order:—

		Godávari District. (Sheet 94).	Nizam's Dominions. (Sheet 74). Pakhal, Modapur, Chinnur	Central Provinces. (Sheets 73 and 74.) Sironcha, &c.
		Alluvium.		
Tertiary ...	...	Rajahmandry sandstones (Cuddalore sandstone of H. F. Blanford).		
Secondary ..	Lameta	Kartairoo traps and intertrappeans.	... ...	Deccan Trap.
		Pangady infratrappeans.*		
Upper Gondwánas.	Jabalpur	Tripetty sandstones... ...	... ...	Chikiala sandstones.
		Ragavapuram shales ...	... ...	Kota and Maleri beds.
	Rájmehál	Golapilly sandstones ...	Sironcha sandstones ...	Sironcha sandstones.
Lower Gondwánas.	Kámthi	Dummapett sandstones ...	Lingagoodium sandstones	? Tarcherla sandstones (at Kaleswarum).
		Chintalpoody sandstones ...	? Tarcherla sandstones	
		Barákars (Beddadanole and Badrachellum, &c.).	Barakars (Kamarum and Singareny).	Barakars (Nandpa, Chanda Sheet).
		Talchirs (Badrachellum &c.). ...	Talchirs (Singareny, Kamarum, Gullady, &c).	Talchirs (Nandpa).
Vindhyans	...	Kadapahs (western side of Sheet 94).	Kadapahs (Pakkal and Chinnur).	Kurnuls, (Nandpa, Kamana, &c. Kadapahs (Naudpa).
Crystalline	...	Gneiss (Garnetiferous) ...	Gneiss (Granitoid).	

THE GODÁVARI DISTRICT.

The Upper Gondwánas, consisting of Tripetty sandstones, Ragavapuram shales, and Golapilly sandstones, occur as a narrow belt of from 10 to 15 miles in width across the district in a west-south-west to east-north-east direction, from the neighbourhood of Ellore

* I think the fossils of the Pangady Infratrappeans (Lameta) show cretaceous affinities.—W. K.

to near Tallapoody on the right bank of the Godávari, and thence by a few distant outliers of the upper group near Innaparazpolliam in that part of the Vizagapatam district included in this sheet of the Atlas.

The main belt rises up at a low angle (5° to 10°) from the western edge of the Godávari delta, or from under the Rajahmandry sandstones and the Deccan traps and infratrappeans of Pangady, and presents a low, sloping and scarped edge to the north-west, or towards the Chintalpoody country of Kámthis, which in its varied surface of hills and plains presents a marked contrast to the uniform surface of the series now under notice.

The grouping of the series is very clear in its main belt between the Godávari and the Ellore river (Tormalair). Uppermost, there is a thin (40 feet) set of dark-brown and red sandstones and conglomerates, essentially ferruginous, with silicio-argillaceous conglomerates and pebble-beds, and bands of concretionary clay-iron-stones. These are ra her softer and more varied in colour towards the bottom, becoming harder and more ferruginous as they are traced upwards, and the upper beds are the heavy ferruginous conglomerates and lateritoid patches which make up the Yernagoodem and Yadavolo country sloping down to the Delta. On a conspicuous point of the north-west scarp is the well-known Pagoda of Chinna Tripetty, whence the name of the group.

The Tripetty beds, in the main area, have as yet only yielded a few indistinct fragments of fossil wood; but from the Innaparazpolliam outliers, which I consider to belong to this group, a small collection of fossils was obtained, from which Dr. Stoliczka inferred that the rocks must be of uppermost jurassic age, because the fossils are allied to those of his Umia beds in the Kachh series.

Below the Tripetty scarp and near Ragavapuram, these sandstones are seen to pass down by softer and less sandy beds into a set of white and buff shales, having a few beds of sandstone near the bottom. Near Ragavapuram, in the slope of an outlying plateau, numerous fossils occur in these shales, among which a *Leda* is the most common form, ranging through all the beds, and with this are associated fewer specimens of *Pecten, Gervillia, &c.*, and a few cycloid fish-scales. About one-third way up the group are some thin yellow and brown flaggy and shaly sandstones, in which specimens of an Ammonite are frequent, with many fragments of *Ptilophyllum* (*Palæozamia*) and a few other plant remains.

The shales form a lenticular patch between the upper and lower sandstones of about twenty miles in length along the scarped edge of the series, being well overlapped at each end by the Tripetty sands, which then rest on the bottom group. Near Talapoody, and as outliers near Innanparazpolliam, the Tripetty beds overlap the lower sandstones and rest directly on gneiss.

The Ragavapuram beds are very like the Rájmehál shales of the Trichinopoly and Nellore Districts; and they resemble, except in being less hard and porcellanic, the fossiliferous shales found last season by Mr. Foote in the Nellore and Kistnah Districts, which contain, I believe, some plants and molusca similar to those of Ragavapuram.

Below the shales comes another set of brown and red sandstones and conglomerates, which, in the main area, have not yet yielded any fossil remains except indistinct fragments of stems. At either end of the belt, these rest on the gneiss, though for the rest of their extent they rest unconformably on the Kámthis or Chintalpoody sandstones; and at one or two points near Kanlacheroo they form small cappings to isolated hills of the same series.

At the Tripetty end of the belt, this lower member is rather thin, and is especially marked by a very heavy dark-brown ferruginous conglomerate, and a strong conglomerate of clear quartz pebbles in a chocolate-brown silicious clay-stone (rather jaspery in appearance) or very hard compact sandy clay-stone.

At the Ellore river, the main band of Upper Gondwánas is separated from a more western area of plateau and scarped sandstones by an interval of alluvium. These constitute the Golapilly country, and it was from the low plateau to the west of Golapilly, near the village of Ravacherla, that I obtained the series of plant remains which led Dr. Feistmantel to consider these sandstones as of Rájmehál age.

This finding of the fossils at once confirmed me in my ideas as to the Golapilly area being an extension of the Tripetty beds and subjacent sandstones; and I was finally led to consider these latter as representing the lower group of sandstones, but considerably thickened out. At the same time, the Golapilly plateaus are, I think, composed in their upper beds of Tripetty sandstones, while the capping of the higher parts, as Doodoogut hill, are of the Rajahmandry sandstones. It is in these higher conglomerates and pebble beds that the old diamond mines or pits are excavated near Mulaily and Golapilly.

Mr. Blanford found, and I have since seen myself, remains of *Glossopteris* and *Vertebraria* at the extreme northern edge of the Golapilly and Nuzaweed area of sandstones near the village of Somavarum; and this naturally led him, in addition to the general lithological characters, to consider the whole area as of Kámthi age. The plateau-form of the low hills even in the Somavarum parts of the area is, however, so constant, and the lithological resemblance between the conglomerates to the south-west of the village and those in the sandstones underlying the Ragavapuram shales is so strong, that I was obliged to look on this area as all of Upper Gondwánas, the *Glossopteris* and *Vertebraria* beds close to Somavarum being merely a remnant of the Kámthis, whilst there is no evidence of unconformity afforded by any striking change in the lie of the beds.

Certainly, between Somavarum and the north-west base of the Doodoogut plateau, the strata are generally unlike Kámthi beds. They are rather fine-grained, thin-bedded and platy *micaceous* sandstones; and these lie on a heavy conglomerate (ferruginous) such as may often be seen in both Upper and Lower Gondwánas, though it struck me that here it is most like the jaspideous conglomerates in the group below the Ragavapuram shales.

As already stated, the wide outcrop of the Upper Gondwána beds with the gentle slope from the north-west, and the plateau-like character of the outlying hills, more especially in the Gollapilly and Sonavarum country, are wonderfully characteristic in contrast to the Chintalpoody country of Kámthis; but a further reason for my thus limiting the area of the Upper Gondwánas is the fact of their gneiss-floor being such as to have aided in giving them their flat lie, and that its evenness of surface does not extend under the Kámthis.

At the Golapilly end of the country, also near Talapoody on the Godávari, and thence east-north-eastward, the crystallines rise from the alluvium in long slopes, remarkably like those of the sandstones, and form plateau-like hills which are escarped to the north-west. Beyond these are further groups of hills and ridges, nearly all of which are more or less flat-topped; their upper surfaces having also a gentle rise to the north-west, until they reach their highest level (about 2,000 feet) in the Papaconda or Bison hill-range, through which the Godávari has cut its great gorge. The same features are likewise seen very clearly in the numerous hills between Golapilly

and Bezwada in the south-west corner of the sheet; and the obvious conclusion is that these flat, elevated areas are really the remains of an old marine floor on which the upper sandstones were deposited.

Near Innaparazpolliam the fossiliferous sandstones are lying or shoring up on the first slopes of this even floor of gneiss. The same sandstones, and also those of the lower group, are shoring up over the denuded gneiss of Talapoody; and this shelving character is clearly evident at Golapilly.

On the other hand, the Kámthis of Chintalpoody, &c., are not lying on any north-west extension of this marine plateau, but are at a generally lower level, and on what must be a much more uneven floor which may, it is true, have been cut out of the old marine plateau, or may even have existed, with its Lower Gondwánas on it, before the Upper Gondwána floor had been pared down.

On the last point, as to the post-Kámthi formation of this floor, there is some evidence in the even strike of the Upper Gondwánas right across the Kámthi area. But this, with the kindred questions as to the direction of the slope of the old Kámthi valley, and the possibly much later age of the present Godávari valley, must be left for future consideration.

LOWER GONDWÁNAS.

No further examination was made of the Kámthis during this season, except in a general way while working along the north-west edge of the Golapilly group, or in crossing to and from the Beddadanole basin of Barákars.

It seemed to me, all through my work, that there may be good reasons for the eventual distinction of the sandstones of Chintalpoody and its neighbourhood, from a higher group to the north represented by very coarse, softish, white, purple and grey sandstones in the plateau hills around Dummapett in the Nizam's Dominions, to the west of Asharaopett. The Chintalpoody group is characterised by rather less coarse beds of more varied colors of red, brown and purple, while they are generally more ferruginous than those of Dummapett. There are also rather marked sets of beds full of nests and lumps of white, yellow and red indurated clay or hard (non-laminated) shale, these being not so much foreign fragments in the sandstone as irregular seams and segregations of clay, for there are often fair laminæ and even thin beds of the same material interstratified with the sands. It was in one of these seams of rather calcareous clay-stone near Kunlacheroo that Mr. Blanford found *Glossopteris* and *Vertebraria;* and I obtained more of these plant remains from another outcrop of the same kind of clays a few miles further to the south.

The Barákars of Beddadanole crop out to the eastward from underneath the variegated ferruginous beds of the Chintalpoody group, and though I am much inclined to suspect that there is unconformity between them as well as overlap, there is no clear section showing this. The association of the Barákars with the Asharaopett Kámthis is the same as I have seen it at Kamarum and Singareny: there is in each case a small patch of the former very clearly overlapped by the latter; and there certainly seemed to me to be a slight difference in the strike and inclination of the strata at certain points, though this after all is what might be expected to occur in beds of such varying thickness and extent as those of the Barákars in the Godávari area.

NIZAM'S DOMINIONS AND CENTRAL PROVINCES.

In marching to join Mr. Hughes in the Sironcha country, I came upon the northerly extension of the Kámthis beyond Pakhál Lake (east of Hannamkonda), to which part of the country I had carried their western boundary in a previous season.

This afforded me an opportunity of again visiting the Kamarum coal-measures, when also the Tálchirs, which I had considered at the time of my first visit to be partly of volcanic origin, were re-examined. In this view I was much mistaken, there being after all only a strong resemblance to volcanic rocks in the peculiarly weathered black and dark-green sandstones, and the quasi-vesicular character of some of these.

To the east of Kamarum, the western edge of the Kámthis is seen very plainly in the hill ridges of Lingagoodium,* which range north-north-west to the Sullavey cross-valley; and beyond is a further group of hills to all appearance of the same series.

In the long valley of Kottapilly, below the Lingagoodium range, traces of Tálchirs are seen, but these could not be traced into contact with the Kámthis, owing to the extensive covering of superficial deposits. Further north, near Sullavey, the Talchirs are again met with in some force, lying, on their western edge, on Vindhyan quartzites and clay-slates, but overlaid by salmon-colored mottled sandstones on the Sullavey side.

The rocks which I have here called Vindhyans are in every way similar to those of the Kadapah series, namely, quartzites (sands and conglomerates) and coarse clay-slates, with occasional thinner bands of grey and bluish-grey splintery silicious limestones weathering brown. These stretch northwards from the Pakhál Lake (which is on the Vindhyans) as a band of some ten miles in width between the Kámthis of Sullavey, &c., and the gneiss of Hannamconda and the country northwards.

I think there is every reason to consider that the Lingagoodium beds extend as far as the groups of hills around Sullavey, that is, from their general appearance and lie; but there is room for doubt as to whether the sandstones in the lower lying country to the north are of the same age. My attention was drawn more particularly to this in my traverse from south to north from Hannamconda to Chinnur near Sironcha. To the eastward of this line the country is marked by many groups of rather high hills, generally presenting their steeper sides to the west and north-west, their strata having a dip to the east and south-east. These hills are all, I feel sure, of the typical brown sandstones of the Kámthis; but unless there be great faulting, of which there did not appear to be any sign, there is a great series of lower sandstones hading out from under the hill strata, and spreading over all the country west of Madapur up to the reach of the Godávari above Sironcha.

These sandstones are generally not so brown and ferruginous, or so hard, as the general run of Kámthis, and among them are soft yellow and reddish-brown beds of very fine texture: neither are they so harsh to the touch. Chocolate and salmon colors are common in the lower strata. A special variety is a rather fine-grained soft sandstone of salmon-red color, containing numerous fragments of pale-red and purple shales and calcareous shales scattered through the rock or, as often, in thin seams of smaller fragments. These contained fragments would appear to be from the Pem shales noticed by Mr. Blanford.

Near Sullavey, the Tálchirs are overlaid by sandstones remarkably like these mottled beds.

* Lingagoodium is 15 miles east of Pakhal Lake, which is 20 miles east of Warungal.

Looking at the physical aspect of the country, and seeing that the general north-west—south-east strike of the Kámthi strata is still maintained among these doubtful sandstones up to and beyond the Godávari, while the dip is also to the eastward, the natural conclusion is that these are lower beds than those of Pakhál and the Godávari District, or that they are of an older group, say the Barákars. They certainly did not strike me as having a Barákar look, though there are occasionally near the bottom of the series thick beds of coarse, soft, light-colored sandstones which might be of this group; but their apparent position with regard to the strata of the Sullavey hills and their lying on the Tálchir patch at that village are worthy of consideration on this view of their possible age. Still, until the country is more closely examined, the preferable conclusion is that they are really part of the Kámthi series and inferior to the strata of Lingagoodium, &c.

It must, however, be mentioned that when Mr. Hughes joined me, he had already been working for some time at these beds between the Malnair and Godávari rivers, west of Sironcha, and was rather under the impression that they belonged to a later series than the Kámthis. If this be the case, they must then have been deposited round the Sullavey hills over the base of the Kámthis and on to the outlier of Tálchirs. To distinguish them as a group, we adopted the name Tarcherla sandstones, from a village on the Malnair river.

At the junction of the Pranhita with the Godávari, just north of the village of Kaleswarum, these Tarcherla beds are overlaid by further strata having very much the same dip, though they differ somewhat in their constitution. There is, however, a local unconformity on the Kaleswarum bank, which, though only small, was sufficient to draw our attention to the possibility of its being more general among the rocks, and that we were here at the bottom beds of a newer series. A bed of fine-grained sandstone with a rather undulating dip to north-north-east at about 5° overlies the partings between five other beds of coarse pebbly sandstone which have a north-east dip of about 10°. This exposure being only about 20 feet in length, and in sandstones which are not constant in the thickness of their strata, it is possible that the unconformity may only be local and a case of oblique bedding, though from the fact of our almost immediately coming on Rájmehál strata above, it is most likely a true break.

At any rate, after crossing the river, and on the right bank of the Pranhita opposite Sironcha, we came on sandstones which differ in many points from those of the country to the south and north-west. They are *micaceous*, thick and thin-bedded, harsh, even-textured grey and brown sandstones, but they at the same time contain fragments of buff and pink shales. These are succeeded, as the short section opposite Sironcha is followed out, by thinner and conglomeratic beds, and these again by some of the thick beds with contained lumps of shale. Above these again is a set of finer grained buff, grey, purple and yellow soft laminated sandstones, rather shaly and flaggy, containing fragmentary plant remains said to be of a Rájmehál type. All the beds are micaceous, and in this differ from the Kámthis. The river section is then covered up by alluvium, and nothing more is seen until a couple of miles south of Anarum, where there is a low rise of friable pebbly sandstones having a flat and undulating lie, and at the village, associated with these sandstones, are grey and purple shaly bands containing plant remains, the only recognizable form being a *Palissya.*

Irrespective of the finding of these fossils, we were quite satisfied of the series (with the exception of the beds containing fragments of shales) being different in character and appearance from the Tarcherla sandstones. At the same time, they do not resemble the Upper Gondwánas of the Godávari District, except in the presence of mica, which mineral is frequent in the Golapilly group of sandstones.

Opposite Anarum at Kota, there is an outcrop of 9 feet of hard, sometimes rough-grained, grey or fawn-colored, splintery limestone with fish remains (bones, teeth, scales, &c.), some of the beds showing very indistinct *Estheriæ*. These limestones are not seen associated with any other beds; but they dip east-north-east, at 10° to 12°, undulating slightly, and it is quite evident from their position that they overlie (with some intervening deposits) the *Palissya* beds of Anarum, and are succeeded by red clays and variegated sandstones a short distance higher up the river bank.

The Kota limestones appear again at Katarapilli higher up the Pranhita, where they crop up to the west-south-west at the usual angle, and must overlie the red clays of Maleri; and, about twenty-four miles still further to the north-west near Bimpur, the Maleri clays are overlaid in situ by limestones of the same kind, with the usual fish remains. Clearly, these limestones are a thick intercalation in the red clays and sands, though the proper fossiliferous clays of Maleri itself, with Ceratodus teeth, crocodilian bones and coprolites are underneath them, while there are variegated sands and red clays above them in the river section at Kota.

About eight miles to the north of Kota, on the left bank of the Pranhita, there is a high scarped plateau-range of hills overlooking the village of Chikiala, the strata of which are newer than those just described; and these must, I think, be considered at present as answering to the Tripetty sandstones of the Godavari District.

The upper red clays of the Sironcha series are visible in the river near Chikiala, but above these no rocks are seen until well up the slopes of the plateau, and then, brown and red ferruginous sandstones and conglomerates appear in great force and so continue to the summit of the plateau. The resemblance between these beds and those of the Tripetty scarps is remarkable; and there are just the same vitreous ferruginous conglomerates, hard silicious and argillaceous conglomerates, and bands of concretionary clay ironstones, as occur in the Godávari and Ellore country. The series seems, however, to be very thick in the Chikiala plateau, and fully the lower half of the slopes is concealed by debris. I did not see any indications of shales like those of Ragavapuram. The Chikiala scarps appeared to be continued away eastward into the Bastar country by still further ranges of flat-topped hills.

Thus, for the Sironcha country, as far as our rapid examination can show, the Upper Gondwánas are represented by the—

a. Chikiala sandstones.
b. Maleri red clays and Kota limestones, and the
c. Sironcha sandstones,

which answer by their fossils in the one case, and the wonderful lithological resemblance in the other, to the—

a. Tripetty sandstones and
c. Golapilly sandstones

of the Godavari District.

Further examination of the fossils of the Ragavapuram shales may show that they and the intermediate group of Sironcha are also synchronous.

KADAPAHS AND KARNULS.

In the Chanda sheet to the north of Nandpa and Sakaravoye, I had an opportunity of seeing the quartzites, limestones and purple shales of the sub-metamorphic series already observed by Messrs. Blanford and Fedden. They strike me as certainly of the Kadapah and Karnul series of Madras, or of the Kaladghi and Bhima series of Western India.

ATGARH BASIN

Scale 4 Miles = 1 Inch.

INDEX OF COLORS & SIGNS

Alluvium Recent. Alluvium Laterite. Trap. Atgurh Sandstone. Gneiss.

Boring Sites.

It is, of course, necessary to remember that both purple shales and limestone, scarcely to be distinguished from each other in regions of disturbance, are found both in the Karnuls and Kadapahs; but as far as I could see, without having had any opportunity of going closely over the ground, the quartzites of the Nandpa hills are Kadapahs, just as I recognise the altered rocks of the Pakhal country to be of the same series. On the other hand, I should certainly consider that the limestones of the trap-capped plateau south of Kamána are Karnuls, or Bhimas.

Between Kamána and Sakaravoye I passed over an extensive belt of purple and grey shales which in some respects are very like certain slaty shales in one of the groups of the Kadapahs; but they do not present that clay-slate character possessed by all the shales of this series, and, on the whole, it would appear that these Sakaravoye beds are of the Bhima or Karnul series.

At the same time Mr. Hughes is of opinion that these purple shales, limestones and quartzites are not distinguishable into two series; consequently, if they are all of one series, they must preferably be considered as belonging to the newer of the two systems, *viz.*, Bhimas or Karnuls; and in certain parts of the field they have been so disturbed and crushed as to have assumed the more altered appearance and characters of the Kadapahs, which is also, I consider, the case with the Kistnah extension of the Karnuls in the Palnád country.

I am, however, hopeful that the Kamána rocks will be found to be separable into the two series, more particularly as they seem to be a north-westerly extension of the Bhimas and Kaladghis, and the shales and limestones are very like the first of these.

ON THE 'ATGARH SANDSTONES' NEAR CUTTACK. *By* V. BALL, M. A., F. G. S., *Geological Survey of India.*

The principal result of my examination of the sandstones and conglomerates which lie to the west and south-west of Cuttack, has been the discovery of fossil plants whose affinities are sufficiently clear to admit of conclusions being drawn as to the age of the rocks which contain them.

That these rocks were of more recent age than the group or groups of rocks which occur above the coal-measures in the Tálchir-field was considered probable by Mr. Blanford*; but the non-discovery of fossils and the similarity of their general lithological characters with those of the rocks constituting the above-mentioned groups have hitherto prevented their certain correlation with the rocks of any recognised period in India.

This uncertainty being removed, the question of the probability of coal-measures occurring underneath assumes a somewhat different aspect, but only perhaps a different aspect. The possibility of such occurrence still exists, even if the probability, in so far as theoretical considerations go, be lessened.

As bearing immediately on this part of the subject, reference need only be made to the Rajmehál hills, where—in part of the area—the coal-measures are directly covered by members of the series to which these rocks are now referred, while in other parts a considerable thickness of rocks belonging to a group distinct from both, intervenes.

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* Records, Vol. V, p. 59.

The next points in the inquiry (the possibility of these rocks directly overlying the coal-measures being thus admitted from analogy) involve a general description of the local conditions, which may therefore be conveniently noticed at once.

The area occupied by these rocks covers about 60 square miles, spreading both to north and south of the Máhanadi Valley above Cuttack. It is covered with low hills and ranges which rarely, if ever, exceed 250 feet in height, and are generally of very much less elevation.

Both the hills and the intervening valleys are covered with a dense, thorny, secondary jungle which, throughout a large proportion of its extent, is absolutely impenetrable. Indeed, the central portion of these hills is an unoccupied waste without villages or cultivation. The trunk road and its vicinity afford an opportunity of examining a cross section in one direction, while the Máhanadi river yields a more or less broken one in another. Otherwise, examination of these rocks has to be conducted round the edges of the area where, however, the junctions are, with a few important exceptions, concealed by alluvium or laterite.

To the north of the Cuttack and Sambalpur road, between Kukkur and Daiserah, there are several ranges of small hills. Towards the east these are chiefly formed of laterite, owing to which, and the density of the jungle, it is impossible to define the limits and nature of the underlying rocks; but even if these obscuring causes were removed, the surrounding alluvium would render exact demarcation impossible. Still, from the existence of metamorphic rocks at no great distance to the north and north-east, there are known limits beyond which the sandstones cannot extend in those directions. Proceeding westwards through these hills, the laterite steadily lessens in amount, and towards their western termination the jungle is the only agent in the concealment of the rocks. Here there are coarse and loose-textured conglomerates with ferruginous sandstones; these rocks appear to be at the base of the group, and probably rest naturally on the metamorphic rocks which are seen not far off on the west.

The same rocks are seen in a stream crossed by the road about a mile east of Daiserah, between which and some schistose gneiss at the river-crossing near Sonkarpur, no rocks are exposed on or near the road. South of the road a spur from the main ranges between it and the river terminates in an abrupt scarp below the village of Hontikul. The rocks exhibited in this scarp consist chiefly of loose-textured, coarse-grained sandstones with occasional pebbles. Towards the top are some white clay beds, in one short length of which, and not elsewhere, I found the fossils described in a following paper by Dr. Feistmantel. The hills which occur to the south and south-west of Daiserah and between it and Malbadapur consist of white and ferruginous coarse-grained sandstones, generally capped by conglomerates, and invariably with horizontal bedding. At Malbadapur metamorphics appear, and the boundary, which seems to be quite natural, strikes southwards through the corner of the large lake or jheel, and thence to the south-south-east, where it passes under the northern end of the Gopalpur hill, where the sandstones and conglomerates are seen at the top, hornblendic gneiss forming the base. The sedimentary rocks alone appear at the southern end of the hill, where it impinges on the river, and are well exposed in section there. From the above it would appear that this portion of the boundary is natural, and that no beds exist between these sandstones and the metamorphics in this part of the area. It may be added that a similar section exists in the end of the hill which lies on the line of boundary between the rise at Gopalpur and the corner of the jheel, but owing to jungle, the section is less clear.

In the river section a slight dip of the sandstones from the boundary towards the east can be observed, but it is only a slight departure from the general horizontal position.

West of the above-described boundary, gneiss crops out in various places, forming low hillocks and ridges. There are two principal varieties: one felspathic containing garnets and sometimes magnetic iron, and the other hornblendic. Close to Kusanpur there is a bossy mass of granitic gneiss striking north-east—south-west, dip north-west.

From hence eastward the section exhibited along the northern bank of the Máhanadi gives the best view of the rocks that can be obtained; but owing to the general horizontality of the beds and the lowness of the hills, the total thickness exposed must be inconsiderable.

Between Gopalpur hill and those which touch the river at Phoolwari, a large fertile bay, encircled by ridges of sandstone, occupies the space, the rocks being covered up by alluvium. In the river channel, too, throughout this interval, no rocks are exposed. At Phoolwari the hills consist of the same sandstones and grits, with pebbles and a pudding-stone strangely resembling one which occurs at the top of the highest hills in the west of the Tálchir field. A dip to the south of these beds, where seen near the bank, I attribute to mere local undermining by the river.

In the channel of the river, below Phoolwari, is a small island formed of sandstones. These on the east shew a dip to south-east, but this, however, also appears to be only local and due to the action of the river.

Between Phoolwari and Balrampur the rocks above and under the river bank appear to be identically the same beds as those above mentioned—in their horizontal extension. In the hill close to the river near Bulrampur there are sandstones with a considerable cap of laterite; under the bank the section of the former discloses a dip of 10°-20° to south and south-west, but further inland the same beds are quite flat.

Between Bulrampur and the Sambalpur road the rocks where seen are of the same general character as before, but on the river bank at Maneshwar there are white sandstones with clays, and on the islet opposite a sandy false-bedded conglomerate of very recent aspect dips south-south-west at 7°.

On the southern bank of the river the sandstones first appear near the village of Naraj, below the Public Works Department bungalow, close to the point where the Máhanadi sends off its branch, the Kajuri. The sandstones here are somewhat loose-textured, strong silicio-felspathic rocks with partings of red and white clays. A quarry in active operation exposes a working face of about 30 feet high. The stones from this locality are largely employed, chiefly as ashlar for the irrigation works. Portions, however, dress fairly, and the general appearance resembles that of the sandstone quarried at Barákar. Inland from this, spreads of laterite and alluvium cover up and conceal these rocks, and in the Sideshar* hill, which is about a quarter of a mile further up the river bank, they are locally abruptly cut off by a vertical dyke of basaltic trap, from the opposite or southern side of which a thickness of about 80 feet of shales dips suddenly away at angles of 10°-12°. The sudden appearance of these shales suggests the existence of a fault, through the fissure caused by

* Under the heading "*Section of a Hill in Cuttack supposed to be likely to contain coal,*" Lieut. Kittoe gives a sketch and account of this hill, to which is appended a note by Dr. McClelland. The sketch, which was drawn by Dr. McClelland, is something in the willow-pattern style of art, but represents the relations of the rocks. Dr. McClelland calls the black and colored shales chalk, a term which is certainly not applicable to them. Neither is the term trachytic applicable to the basaltic trap. Some calcareous matter is stated to occur at the junction of the trap with the clay shales forming "a true vein," in which there are said to be "fragments of primary clay mechanically mixed with plates of silvery mica—ingredients which must have been derived from below." This vein was filled with rubbish from the top at the time of my visit. The occurrence of the clay-slate and mica is probably to be accounted for by a partial metamorphism caused by the dyke.

J. A. S. B., Vol. VII, 1838, p. 152.

which the dyke was doubtless thrust. Although the section in the river bank is quite clean, the thick covering of laterite on the hill and from thence inland renders it impossible to trace the limits of the trap and examine its relations with the sandstones in that direction. These latter, however, appear to sweep round the Sideshar hill to the east with unbroken bedding; further south, however, both shales and basalt are again met with, as will presently be noticed.

The trap on the river face extends for about 150 or 160 yards in a north-east, south-west direction, but this is probably oblique to the strike, and certainly so if the trap seen further south is continuous with it. It is a dense, heavy, greenish-black rock abounding in an earthy magnesian mineral, which in the exposed portion has been washed out and left hollows.

On the southern side of the trap occur the shales above mentioned; of these the lower portion is black and carbonaceous, but not in the smallest degree coaly; towards the top they become purplish and red, and include one or two distinct runs of ironstone. Unfortunately they do not shew any determinable remains of plants, a few charred fragments of vegetable matter being alone discernible. In general appearance, beyond the fact that they are carbonaceous, these shales do not present any resemblance to those of the coal-measures, while they are of much the same character as certain well-known beds in the intertrappeans of the Rájmehál hills. The hopes of coal occurring in this vicinity, which have from time to time been excited by the appearance of these beds, are not, I venture to say, justified by the facts. The appearance of these beds at the surface, in this locality, being probably altogether due to the elevatory action of the trap, and the fact that they have not been elsewhere observed in any part of the area, prevent any decided opinion being formed as to their extent. Judging, however, from the sections in the Rájmehál hills, it is not improbable that they may originally have had a very limited area of deposit.

The point at which they appear further south is situated about 500 yards to the east of the village of Mondali. Here, together with the trap, they have contributed to the formation of the soil, and are seen in certain shallow wells and excavations, but nowhere crop out at the surface.

Close to Mondali there is an unusually hard and dense felspathic quartzite. In the river section, at intervals up to Bajipur, there are outcrops of sandstone of normal character. In the vicinity of the bund in the direction of the river, certain black clays situated in the bank at about the hot-weather water-level, and which had been pointed out to me as being possibly indicative of coal, proved on examination to be of a peaty character and of the same age as the alluvial clays with which, indeed, they may be seen to be interbedded. Between this and Dompara the beds exposed in the river are flat, ferruginous sandstones, rarely accompanied by red clays. In the hills to the south of the road there are sandstones and conglomerates similar to those seen in the ranges north of the river.

Towards Talbust, a hill of metamorphic rocks occurs in close proximity to the sandstones, but no junctions were observed. The boundary is still probably natural, as the sandstones shew no signs of disturbance. Between Talbust and Huldia the rocks seen are massive beds of coarse sandstones and conglomerates, which are in places abruptly scarped.

Between Huldia and Maindasal, at the foot of the Tuskai hills, the boundary is completely hidden by laterite, under which the sandstones disappear. Springs are very abundant at the foot of the hills.

To the north of Mandasal there is a considerable area traversed by the road, in which metamorphic rocks occur. Owing to laterite, the limits of this area and the relations between the gneiss and quartzites occurring in it, with the surrounding sandstones, are very much obscured.

Between Mandasal and Bobaneshwar, sandstones of the same character occur, forming at Kandagiri the small hill famous for its enormous *gumpas* or cave temples. To the southwards and also to the east, at a point about a mile to the west of Bobaneshwar, the sandstones disappear under great spreads of laterite. The eastern limits of the sandstones in the country stretching northwards between this and Naraj are also effectually concealed by laterite. It is quite possible that the sandstones may stretch eastward for several miles under the alluvium of the delta.

Although in the foregoing pages these rocks have generally been spoken of as occurring horizontally, it seems to be the case that, viewed as a whole, there is a slight dip to the south-east.

Having now described the appearance of these rocks and enumerated the various data available, the question as to the probability of coal-measures occurring underneath them may now be resumed.

That there is no inherent impossibility of such being the case has been already demonstrated on a previous page. A basin of coal-measures, the edges of which have been overlapped, may possibly occupy the centre of the area, and it can only be in view of such a possibility that any exploration can be undertaken. As a matter of observation, the beds of sandstone are horizontal, or are practically so, and whenever their boundaries are not obscured by alluvium or laterite, and, consequently, the underlying rocks are exposed, the latter invariably prove to belong to the metamorphic series.

Owing to the occurrence of such metamorphic rocks at or close to the boundaries of the sandstones on the north, west and south sides, respectively, it is clear that if the hypothetical basin exists, its limits are overlapped in those directions, and it therefore follows that exploration by boring, if undertaken, should be directed chiefly to the eastern central portion of the area. For this purpose the vicinity of the trunk road is well situated, besides possessing other manifest advantages. Further to the east, and even in the station of Cuttack itself, borings might be made, which, in so far as anything is certainly known to the contrary, might be regarded as having an almost equal chance of proving coal-measures. But the difference in chance, slight as it is, together with the difficulty of carrying out a boring through a possibly considerable thickness of alluvium, should, I think, determine in favor of the former.

On the accompanying map I have marked the localities in which the borings might be made, the numbers indicating roughly the order of their relative importance. Nos. 1 to 5 would be the most important. If they proved, as they might do at a very small depth, that metamorphic rocks underlie the sandstones, without any coal-measures intervening, then it would be useless to proceed with the others.

In conclusion, I wish to make it quite clearly understood, that the indications do not appear to me to be such as to justify any good hopes of success, and consequently I cannot recommend any further expenditure being incurred for exploration by boring or otherwise. The decision as to boring-operations being undertaken resting with the Government, and the possibility of there being hereafter such a local demand for coal as to make it desirable to put the matter to a final test, are my reasons for having discussed the question of boring as above in detail.

List of sites for borings in approximate order of their relative importance.

(1) North of Chandkar	On the Madras road, south of the Máhanadi.	
(2) At Kujmul (Koojmool)		
(3) One mile east of Barcul (Burcool)		
(4) ½ a mile north-east of Fulghar	Near Naraj, on the Máhanadi.	
(5) ½ a mile south-east of „		
(6) One mile west of Goyrbank	On the south bank of the Máhanadi.	
(7) South of B. Patpur		
(8) At Bolpada	On the north bank of the Máhanadi.	
(9) At Kandarpur		

NOTES ON FOSSIL FLORAS IN INDIA, *by* OTTOKAR FEISTMANTEL, M. D., *Palæontologist to the Geological Survey of India.*

IX, X, XI, XII AND XIII.

IX.—ON SOME FOSSIL PLANTS FROM THE ATGARH SANDSTONES.

The flora of the Atgarh sandstones, so far as known, is poor in species, but nevertheless sufficiently marked to enable us to recognise the period to which it belongs. Ferns prevail.

FILICES.

ALETHOPTERIS INDICA, *O. and M. sp.* (PECOPTERIS, *O. and M.*).

This species is tolerably abundant. It was first described by M.M. Oldham and Morris in the flora of the Rájmehál hills (Pl. XXVII). I have elsewhere shewn that this Rájmehál species is very near to ***Asplenites Rosserti***, Schimp. Lately I have found it to be not uncommon amongst the fossils from Golapilly near Ellore, and have made use of its occurrence there together with that of other fossils to prove that the Golapilly rocks belong to the Rájmehál group. The present is an analogous case from which a similar conclusion may be drawn.

Besides the common form of *Alethopteris indica,* O. and M. sp., there occurs a still smaller frond which, however, belongs also to *Alethopteris,* Göpp.

If we compare the drawings of M.M. Oldham and Morris' work (Pl. XXVII), we find that fig. 2 shews slightly different dimensions; similarly is the *Alethopteris* from Atgarh different from the common form. In order to mark the distinction, I would call the latter *Alethopteris indica,* O. and M. var. *minor.* This form is somewhat rare, the occurrence of the other being much more frequent.

ASPLENITES MACROCARPUS, *O. and M. sp.*

There is a fragment of a pinna, the pinnulæ of which show a slightly dentated margin, with an indication of fructification, as is also to be seen in *Pecopteris macrocarpa,* O. and M. I do not doubt that this fragment from Atgarh should be referred to this species. I have transferred it to the genus *Asplenites,* retaining the original specific name.

This species occurs pretty frequently among the fossils from the Rájmehál hills, and also occurs with those from Golapilly. I hope to make a comparison between this species and *Asplenites Ottonis,* Schimp., from the Rhætic strata.

GLEICHENITES BINDRABUNENSIS, *Schimp.*

There are some specimens of a fern which at once recall the species from the Rájmehál hills described by M.M. Oldham and Morris as *Pecopteris* (*Gleichenites*) *Gleichenoides*. Mr. Schimper considered it, however, to belong to *Gleichenia*, and has described it as *Gleichenia Bindrabunensis*, Schimp. This I believe to be correct, and I therefore adopt his name for the species.

The above species of ferns have already been recognised as characteristic of the Rájmehál group. I do not doubt that they here indicate the same group.

As appendix to the ferns I may mention the occurrence of the genus *Rhizomopteris*, *i. e.*, Rhizomes of ferns, which I describe especially further on.

CYCADEACEÆ.

Cycadites confertus, Morr. A single leaflet establishes the species; it agrees completely with Pl. VIII, fig. 2, in Oldham and Morris' Rájmehál Flora. As I think, the *Cycadites Blanfordianus*. Oldh., is to be placed to this species.

CONIFERÆ.

A branch, pretty well preserved, belongs no doubt to that species which was, for the first time, found in the Rájmehál hills and figured, but not described; in the Rájmehál Flora, (Pl. XXXIII) under the title *Taxodites indicus*, O. and M.

Subsequently Mr. Oldham himself admitted that this fossil belongs to the genus *Palissya*. I also have recognised it as such, and moreover proved it to belong there. The same form has been found also in the Jabalpur group of the Satpura basin. I have also identified it from Golapilly and Kach (Cutch). When describing it in my papers on the Kach (Cutch) and Rájmehál floras and giving the *diagnosis*, I thought it best, on transferring it to the genus *Palissya*, to call the species after Dr. Oldham, *viz.*, *Palissya Oldhami*, Fstm. I also published the same name in my notes on some fossil floras from India (Rec. 1877, Pl. II). This I thought to be justified by the fact that the species has never been described. My intention to thus change the name has, however, been objected to; so that to avoid any misunderstanding I have decided to use for this conifer form from the Rájmehál hills, Satpura, Kach, and Golapilly the former species name—*indica*. It will therefore stand as *Palissya indica*, Fstm., to which species also belongs our plant from Atgarh.

The specimen from Atgarh is a single branchlet, but quite distinct, the midribs in the leaflets being visible.

Genus: RHIZOMOPTERIS, *Schimper*, 1869.

Schimper: Pal. végétale, Vol. I, p. 699.

Nathorst, 1876,* page 14, Pl. I, figs. 8-13.

Rhizomes of ferns, either underground or superficial, distinct by their repeated ramification. They show the scars of the fallen-off peduncles, or contain the remains of the petioles, often covered with pile.

Schimper established this genus from two forms from the carboniferous formation. Lately, Mr. Nathorst described one species from the Rhætic of Sweden,* *Rhizomopteris Schenki* from Palsjo (l. c. p. 14, Pl. I, figs. 8-13).

* Nathorst: Bidrag Till Severiges fossila flora, Stockholm, 1876.

Amongst the fossils brought by Mr. Ball, some specimens are to be referred to this genus. I describe them as—

RHIZOMOPTERIS BALLI, *Feistm.*, Pl. I, figs. 2-7.

Rhizomate dichotome ramoso, cicatricibus petiolorum vestito, circiter, 10-14. Cm. crasso, ramis adæquantibus cicatricibus in quincunciam dispositis, circularibus subemarginatis fossula circulari circumdatis.

The rhizoma apparently dichotomous set with scars, which are disposed in quincunx. They are circular, and surrounded with a circular line.

The specimens from Atgarh agree mostly with those described by Mr. Nathorst, especially Pl. I, fig. 10, while the other ones figured by Nathorst shew larger scars with a horse-shoe-like vascular mark, but fig. 10 has the same circular scars as the Atgarh specimens. On two or three specimens the ramification (dichotomy) of the Rhizoma is well seen. In size they resemble also mostly those from Palsjo.

Rhizomopteris, Schimp., takes in the Fossil Flora amongst the ferns the same part as *Spiropteris*, Schimp., which comprises the circinnate vernation of fossil ferns, as *Rhizomopteris* comprises the rhizomata; and there can, of course, be as many different species of *Rhizomopteris* as species of ferns, supposing that all different species of ferns have also different rhizomes, but it might be very difficult to decide to which fern a certain *Rhizomopteris* should belong.

Here in the Atgarh strata near Cuttack ferns are prevailing, and the *Rhizomopteris* belongs to one of them. The species I devote to Mr. V. Ball, who collected it.

Some of the forms, which Mr. Schenk (Flora der Grenzschichten, 1867) figured as "*trunci filicum*," belong perhaps rather to this genus; and then the stem fragments from the Mangli beds, which I referred as very similar to Schenk's "*trunci filicum*," are perhaps also rather to be placed with *Rhizomopteris*. Now I think that also the specimen from Kach, which I figured, Pl. IV, fig. 3,* and discussed shortly (page 35) as Stem of "fern" (or Rhizome), would be rather a *Rhizomopteris*.

X.—ON TRUE PTEROPHYLLUM FROM THE RANIGANJ FIELD, AND THE CYCADEACEÆ FROM THE DAMUDA SERIES.

Already in 1850 Dr. McClelland† described a real *Cycadeous* plant from the Damuda Series near Raniganj with the name *Zamia Burdwanensis* (Pl. XIV, fig. 4, p. 53 l. c.) This figure, however, he has taken from a set of unpublished plates of Burdwan fossils in possession of the Asiatic Society.

When subsequently Mr. Oldham wrote his paper on the age and the geological relations of the rocks in Central India and Bengal,‡ he thought justified, on account of the general badness of the drawings, as he had not the original before him, in doubting the accuracy of this figure, *Zamia Burdwanensis*, McCl.; and he could not help thinking that a fragment of a *Schizoneura* had in this case been mistaken for a *Zamia*.

Only lately, however, this disputed and very important specimen was found by Mr. Medlicott amongst some old collections. It shews that McClelland was completely

* Flora of Kach: Palæontol. Indica, 1876.

† Report of the Geol. Surv. of India for 1848-49, Calcutta, 1850.

‡ Memoirs Geol. Survey of India, Vol II.

GEOLOGICAL SURVEY OF INDIA

O. Feistmantel. Pterophyllum and Rhizomopteris. Records Vol. X.

J. Schaumburg, ad natur Lith.

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right in considering it as a *Zamieæ* (though not *Zamia*). His figure agrees pretty fairly in outline with the original, so that there is no doubt that we have before us that specimen from which the figure in those unpublished plates was taken and which McClelland copied again; only the insertion of the leaflets and the veins are not quite correctly drawn. From these both, as also from the form of the leaf, I think that this specimen is rather a *Pterophyllum* than a *Zamia*.

I shall give here a short description, and as McClelland called it already *Zamia Burdwanensis*, I shall keep the same specific name; I give also a new figure of it.

PTEROPHYLLUM BURDWANENSE, *Feistm.*, Pl. I, fig. 1, 1*a* (McClell., sp.).

1850. *Zamia Burdwanensis*, McClelland: l. c. p. 53, Pl. XIX, fig. 4.

Fronde mediocri, rhachide tenui (in specimine nostro!); pinnulis (foliolis) oblonge linearibus, æqualibus, subcoriaceis, tota basi insertis; basi paulo dilatatis, contiguis, apice obtuse acuminatis; nervis simplicibus, filiformibus, distantibus, 7-8 numerantibus.

The specimen is only a fragment of a frond, with four leaflets on one side and two on the other; the frond seems to have been only of a middle size, as far as one can judge from the specimen. The leaflets measure 62 mm. length and are 8 mm. broad.

They are inserted by the whole base, and they seem to be slightly joined at their bases; the apex is obtusely acuminated. The rhachis of the frond in this specimen is very thin; it does not, however, follow that it was so throughout, as we see, for instance, the same relations in *Pterophyllum Medlicottianum*, O. M., from the Rájmehál hills; the specimen figured by M.M. Oldham and Morris* has a thin rhachis, while I have figured later two specimens, with a pretty thick rhachis.†

The veins are not numerous and rather distant; I could count seven to eight veins in one leaflet; they are very thin, though very well marked.

As to the relations of our specimen, I can say that it is next to those forms from the Rájmehál hills which were named *Pteroph. Carterianum*, Oldh., and *Pteroph. Falconerianum*, Morr., both of which, however, I treat as only one species, with the former name.

This species increases the number of the *Cycadeaceæ* from the Damuda Series. As I have mentioned in one of my last notes in the Records, I think it is very probable from the form of the leaf and especially from the relations of the veins that the *Zeugophyllites* from Australia, which by some authors is also referred to *Schizoneura*, is only a *Cycadeaceæ*, and belonging most probably to *Podozamites*, Br.

This *Pterophyllum* is, however, not the only *Cycadeaceæ* from the Damudas. I mentioned already several others which according to the opinions of most authors (beginning with Brongniart, 1838, and ending with Schimper, 1874) are to be placed to *Cycadeaceæ*.

To these belongs in the first place—

NÖGGERATHIA, *Stbg.*

Nöggerathia, Strnb., is in our Damuda Series pretty frequent, and a *Nöggerathia Hislopi* was described by Sir Charles Bunbury 1861.‡ It is very well known that Brongniart already, 1833§, was convinced that *Nöggerathia* belongs to the *Cycadeaceæ*; later

* Rajmahal Flora: Pal. Indica, Pl. XVII, fig. 1.
† Rajmahal Flora Contin., Pl. XLIII, 2, XLIV, 1.
‡ Quar. Jour. Geol. Society, 1861.
§ Annales des sciences naturelles, 1833.

(1850) Goldenberg* was of the same opinion. Sir Charles Bunbury in general adopted Brongniart's views about *Nöggerathia*, and it seemed to him only doubtful whether it could not be a fern; but "the breadth and coarseness of the veins in the Nagpur plant, and a certain appearance of rigidity about the leaf," looked already to Sir Charles Bunbury rather like a cycad than a fern (l. c. p. 335), while the dichotomy of the veins, their equality and uniformity, and the absence of any trace of transverse connecting veins, plainly shews that it is not a Palm (l. c. 335), so that he would refer the plant rather to the *Cycadeaceæ* or an allied form. The resemblance of *Nöggerathia* in its well-defined characters with some *Zamieæ* is so striking, that there can be little doubt but that it belongs to this Order or very near. Already in previous papers (in Europe) I have considered *Nöggerathia* as gymnospermous, as also Professor Geinitz does. Schimper placed it (1870-72) quite distinctly with the *Zamieæ*, as first genus; and also in my Flora of Kach† I quoted *Nöggerathia* with the *Cycadeaceæ*, uniting *Nöggerathia* with *Cordaites* to a special family, which, however, is only partly so, as some *Cordaites* may belong elsewhere, while *Nöggerathia* remains a *Cycadeaceæ*.

If we compare the carboniferous *Nöggerathia foliosa*, Stbg., with *Sphenozamites Rossi.*, Zigno, there is certainly a great similarity between them; and if we compare the fructification in Goldenberg (l. c. Pl. III, fig. 3) with the fructification of a living *Zamia*, there is certainly a striking resemblance. Our Damuda *Nöggerathia* resembles very much the leaves of some living *Zamieæ;* so that all evidence seems to prove the views of Brongniart, that *Nöggerathia* is a *Cycadeaceæ* and most probably a *Zamieæ*.

The *Nöggerathia* from the Damuda Series supports strongly this view; and there is especially a specimen from Barkoi in the Satpura basin since many years in our collections which shews two leaves in their natural position as they were inserted on the stalk.

Genus: MACROPTERYGIUM, *Schimp.*

Some of the triassic forms, which at first stood also with *Nöggerathia* and *Pterophyllum*, were lately separated by Mr. Schimper with a special name, *Macropterygium*, with two species, *Macropterygium* (*Nöggerathia*) *Bronni*, Schimp., and *Macropteryg.* (*Pterophyllum*) *giganteum*, Schimp. Of these one is also in our Damuda Series; I mentioned already in Records IX, 4, p. 141, a specimen from the Lower Godávari District as *Nöggerathia Vogesiaca*, Bronn., which is Schimper's *Macropterygium Bronni*, and there are from the Damuda Series in the Satpura basin for a long time exhibited several specimens of a *Nöggerathia*-like form, only that they are much longer than the usual forms, and I suppose them to belong to *Macropterygium*, somewhat allied to *Macropterygium Schenki;* a similar form I brought again this year from the Kurhurbalee coal-field, together with many other plants on which I shall report on a subsequent occasion.

As far as is known now (1877), cycadeous plants are not so rare in our Damudas, at least more frequent than we find them in Carboniferous and Permian strata. There are known, not regarding those cycadeous plants which I brought from the Kurhurbalee coal-field and which are not yet described, four genera of *cycadeous* plants in our Damudas; as it is rather an important point in the discussion on the relations of our Damudas, I shall give here the general view of the genera and species known to present date, with their localities and dates of discovery.

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* Verh. d. naturf. Rheinpreuss Vereins, 1848, V.
† Pal. Indica, 1876, p. 38.

ZAMIEÆ.

1. Genus: NÖGGERATHIA, *Sternberg*, 1828.

Nöggerathia Hislopi, Bunb., 1861. Already known to Rev. Hislop, and in 1861 described by Sir Charles Bunbury (Q. J. G. Soc.), who was not quite certain about the nature of this genus, but would rather refer it to the *Cycadeaceæ* or a neighbouring family.

Is known from Nagpur district (at first known from there), from the Satpura basin (many years in the collections).

Nöggerathia sp., from Kurhurbalee coal-field, known since 1871 and brought again this year. The same form occurs in the Tálchir shales.

Genus: MACROPTERYGIUM, *Schimper*, 1870-72.

Macropterygium comp. Bronni, I think a specimen (respect. two, as positive and negative impressions) from the Lower Godávari District (since 1873 in the collections), belongs to this genus, and also very near to the same species. So much is at least certain that they are *Cycadeaceæ*.

Genus: PTEROPHYLLUM, *Bgt.*, 1828.

One species is known.

Pterophyllum Burdwanense, Fstm. (McClell. sp.), which I describe now with this name, but which already by McClelland was figured (1848-49) as *Zamia Burdwanensis*. From the Raniganj coal-field.

Genus: GLOSSOZAMITES, *Schimp.*, 1870.

Glossozamites Stoliczkanus, Fstm. Only lately described by me, but since 1871 amongst our fossils from Domahani, Kurhurbalee coal-field, with a small suite of other plants, amongst which three coniferous branchlets already at that time were determined as *Voltzia heterophylla*, Bgt., which I found again so frequently this year.

These *Cycadeaceæ* from Kurhurbalee coal-field are the more important, as from the close connection of the Kurhurbalee coal-bed and the Tálchir strata, as regards both the stratigraphy and palæontology, I consider the Kurhurbalee beds as the lowest, or at least as low as the other representatives of the Barákar group and the Tálchir shales in close connection with it.

From the importance which the *Cycadeaceæ* have for us, I thought it useful to draw attention to these remains before they can be published with full descriptions and figures.

XI.—NOTE ON PLANT FOSSILS FROM BARÁKAR DISTRICT (Barákar group).

In the beginning of this year I had an opportunity of visiting those beds of the Raniganj coal-field which were designated as the Barákar group. I procured many fossils from the mines in Kumardhubi (near Barákar), and collected some also in the most western part, near Nirscha.

The fossils, which come everywhere from above the coal seam and partly from bands in it, show a great uniformity of forms, and are throughout the same as we find them in the

"iron shales" and in the Raniganj group of the same coal-field excepting the *Schizoneura*, which occurs as well in the Panchet group.

I determined from near Kumardhubi—

EQUISETACEÆ.

1. *Phyllotheca indica*, Bunb.—Stalks of equisetaceous plants determined with this name.
2. *Vertebraria indica*, Royle.—Very frequent; good specimens.

FERNS.

3. *Glossopteris communis*, Fstm.—A form with a pointed leaf, with incurved veins forming very narrow meshes. Very common through the whole Damudas.
4. *Glossopteris* with parallel, long and wide meshes.
5. *Glossopteris* with straight veins, forming narrow meshes.
6. *Glossopteris* with very wide and long meshes These will be described subsequently.
7. *Gangamopteris*.—Some two or three fragments I suppose to belong to *Gangamopteris cyclopteroides*, Fstm.
8. *Tæniopteris*.—Two specimens, with narrow veins.
9. *A Fruit*, which is not unlikely a cycadeous fossil.

From the western part near Nirscha I determined—

EQUISETACEÆ.

1. *Vertebraria indica*, Royle.

FERNS.

2. *Glossopteris stenoneura*, Fstm.—With very equal, long and very narrow meshes.

Of these *Vertebraria indica*, *Phyllotheca indica*, and most of the *Glossopteris* species, occur also in the Raniganj group; if we now add, that in the Barákar group of Tálchir near Cuttack there is known *Sphenophyllum trizygia*, Mig., *Sphenopteris polymorfes* (the same as in the Raniganj group), besides most of the *Glossopteris* species, there certainly remains almost only *Schizoneura Gondwanenis*, Fstm., as peculiar to the Raniganj group, while most of the other fossils it has in common with the Barákar group, and moreover all the fossils which have been found as yet in the Iron Shales are identical with the same, both in the Raniganj and Barákar groups.

The close relation of the Raniganj group with the Panchet group (see further on) is unquestionable, by the continuation of the same *Schizoneura Gondwanensis*, Fstm.; so that all these circumstances shew distinctly rather a continuation of forms from one band to the other, than any distinct break or interruption of deposition and of life, and support, therefore, the view of a more uniform epoch of time.

The Kurhurbalee coal strata of which I shall speak in a following number are certainly as old as the Barákar group in other districts, if not lower, as they are so closely connected with the Tálchirs in stratigraphy and fossils; and as the Kurhurbalee flora has most allies in Triassic times, the other strata can scarcely be older.

XII.—Fossil plants from near Assensole (Raniganj group).

Staying at Assensole, I visited the Nunia to see the Panchet group. In a north-west direction the stream traverses first some strata which were termed the Panchet group, where the *Schizoneura Gondwanensis*, Fstm., was collected. I failed to observe the slightest unconformity or difference between these strata and those in which the outcrop of coal with fossils of the Raniganj group occurs above the village Khumarpur; so that, here at least, the stratigraphy would admit of the relation I have suggested from the fossils. The coal seam outcropping in that part of the Nunia stream and the strata with it have quite the same dip as the overlying strata assigned to the Panchet group. Some strata above the outcrop are not to be distinguished from those of the Panchet group, and contain *Glossopteris*, so that I have no doubt that this genus passes into the Panchet group. The respective specimens are in our collections.

Below the coal-seam a thick band of fine-grained sandstone of yellowish color, full of *Vertebraria indica*, Royle, is lying. No other fossils were found in it.

In the carbonaceous shale with the seam I collected—

1. *Vertebraria indica*, Royle.
2. *Glossopteris*, with wide meshes, like those I mentioned from the Barákar group.
3. *Glossopteris*, with a round leaf, some of which I know from Raniganj. It will be described together with those from Raniganj.

Completely the same *Glossopteris* with wide meshes I observed in the mines of the Beerbhoom Coal Company near Dadka. The seam is the same. It lies in the Nunia stream almost on the boundary marked on the map between the Raniganj and Panchet groups in that locality. It has exactly the same dip (south) as the overlying strata, the same relations as have the Tálchir strata, to the overlying coal strata in Kurhurbalee coal-field. In a southern direction from Assensole I followed the Nunia to beyond Beldánga. South-east of this place a seam crops out with a southern dip. As in the outcrop in the northern part of the Nunia, the shales were much decomposed by the influence of the water, so that with great difficulty only a few plants could be got out. It was especially a very thin stratum of shale above the coal which contained the fossils; I could determine the following species:—

1. *Vertebraria indica*, Royle, is the common form.
2. *Phyllotheca indica*, Bunb.—Some equisetaceous stalks.
3. *Glossopteris.*—Prevailing, a form with very narrow leaves, of which the veins, however, were different from those in *Glossopteris angustifolia*, Bgt. I refer it to *Glossopt. leptoneura*, Bunb., from Kamthi; again another species to connect the Raniganj and Kámthi groups as the same horizon.
4. *Gangamopteris*—A species with a narow leaf, though different from *Gangamopteris angustifolia*, McCoy. I shall describe it hereafter; it is from Beldánga.

It is the second instance of this genus in the Raniganj field, which is so frequent in the Kurhurbalee field, and almost the only fossil in the Tálchirs; in the latter two the species are identical.

The localities of fossils mentioned above are new for us as such, but they shew again the same character of flora as we are accustomed to see in other localities in the Raniganj and Barákar groups.

XIII.—Explanatory note on Glossopteris and Gangamopteris.

I wish to make a few remarks explanatory of some statements in my paper on the homotaxis of the Gondwána system.* I do so at the request of Mr. W. T. Blanford, and most willingly, as it may explain some misunderstandings which I never intended.

Both these statements are on page 122. The one refers to the occurrence of *Glossopteris* in Australia. When I said that there would with great difficulty be found one species common with our Damudas, I referred to the lower beds, because, as far as I know the fossils, it is so; while with the *upper* beds (I mean those without animal fossils) there will be more species identical. My contradiction referred, therefore, to the identity of species of *Glossopteris* in the Damudas and lower coal-beds in Australia.

The second statement which I have to explain is about *Gangamopteris,* which Mr. W. T. Blanford mentioned as having been detected by me in the lower coal-beds in Australia. I must confess that from a cursory inspection a specimen seemed to me to be *Gangamopteris,* and I mentioned this determination to Mr. Blanford, without, however, the intention of having it published. When Mr. Blanford published this determination, which afterwards proved wrong, I had to contradict it, but omitted to say that the fault was on my side, as the determination was only a superficial one and not correct.

NOTICES OF NEW OR RARE MAMMALS FROM THE SIWALIKS, *by* R. LYDEKKER, B. A., *Geological Survey of India.*

Since my last notice of Siwalik Mammals, Mr. Blanford has sent from the Manchhar (Siwalik) rocks of Sind a small, but very interesting, collection of mammalian teeth; among the species in this collection the following are new to the Sind area, *viz.*:—

Sanitherium Schlagintweitii, Meyer.
Chæromeryx silistrensis, Pentland, sp.
Hyopotamus palæindicus, sp. nov. nobis.
Merycopotamoid, gen. non. det.
Sus hysudricus, Falc. and Caut.
Acerotherium perimense, Falc. and Caut.
Amphicyon palæindicus, nobis.

Of the most important of these specimens I now give short notices, preparatory to fuller descriptions and figures; in the present paper I have also noticed specimens of the teeth of two genera of Mammals new to the Siwaliks, collected by Mr. Theobald in the Punjab; the upper molars of a new genus of Siwalik *Hippopotamoid* are also shortly described; as well as two lower molars of what appears to be a new species of Trilophodont *Mastodon.*

ARTIODACTYLA.

SANITHERIUM SCHLAGINTWEITII, *Meyer.*

This genus has been hitherto known only by some molar teeth of the lower jaw, from Kushalghar, which will be found figured on Pl. 9 of "Indian Tertiary and Post-Tertiary Vertebrata:"† among Mr. Blanford's collection there are two upper molar teeth

* Rec. Geol. Survey, India, IX, 4.
† Palæontologia Indica, Ser. X, part 2.

of a small suine animal, which cannot be referred to any European fossil genus, and which from their size I have no doubt belong to the present species. The masticating surface of one of these teeth is raised into four cones, separated by a cruciform valley, of which the antero-posterior division is very shallow; there is an accessory cone behind the two anterior cones; the whole crown is surrounded by a crenulated cingulum; the dimensions of one of the specimens are as follows:—

	Inch.
Length	·55
Breadth	·52
Height of crown	·29

The excess in size of this tooth over the lower molar of *Sanitherium Schlagintweitii* is proportionate to the excess in size of the upper over the lower molars of the pig. The upper molars seem to be nearest to those of *Chærotherium*, but are distinguished by the greater proportionate length of their antero-posterior diameter, and by the larger size of the fifth tubercle on the masticating surface.

CHŒROMERYX SILISTRENSIS, *Pentland, sp.*

This genus has been hitherto known only by three specimens of upper molars from Caribari (Garo hills, N. E. Bengal)* which were originally figured by Pentland in the second volume of the second series of the "Transactions of the Geological Society of London," under the name of *Anthracotherium silistrense;* the genus *Chæromeryx* was subsequently made by M. Pomel† for the reception of these specimens: the original specimens are now in the Museum of the Geological Society. Figures of these specimens are also given on Pl. 68 of the "Fauna Antiqua Sivalensis." Mr. Blanford has sent down a single right upper molar tooth of this species, which exactly corresponds with the larger of the original specimens, and which therefore requires no further description here. This rare tooth is extremely valuable as shewing that the Bengal rocks are on the same horizon as the typical Siwaliks of Sind. It is very remarkable that the only known teeth of this genus have been found in two localities so far removed from each other as Sind and N.-E. Bengal.

HYOPOTAMUS PALÆINDICUS, *n. sp. nobis.*

Up to the present time the last noticed genus has been the only one of the pig-like animals with five-columned teeth which has been found in India; the exclusively Indian genus *Merycopotamus* differing from its European congeners by having only four columns on its upper molars. Among Mr. Blanford's collection there are two upper molar teeth, one much worn, and the other only touched by wear, which belong to a species of Selenodont pig-like animal, but which carry five columns on the crown, in place of the four of *Merycopotamus;* the additional column occurs between the outer and inner columns of the anterior half of the tooth, occupying the same position as in the genus *Hyopotamus.* The general form of the tooth is very like that of *Hyopotamus velaunus;* the outer surfaces of the outer pair of columns of the Indian specimens have, however, a larger median ridge, and in this respect resemble *Merycopotamus.* The form of the worn dentine surfaces is like *Hyopotamus.* From the presence of five columns on the crown of the Sind specimens, I have referred the specimens, at all events provisionally, to the genus *Hyopotamus,* with the specific name of *palæindicus;* further discoveries may shew that the specimens belong to a new genus intermediate between *Hyopotamus* and *Merycopotamus:* in any case, the specimens are of great interest, in shewing that the two last mentioned

* The locality is given by Colebrooke (Tr. G. Soc., Lon., Ser. II, Vol. I, p 132)—the left bank of the Brahmaputra, above Mohendroganj. The river has moved westward since then.

† Compt. Rendus, 1848, p. 687.

genera are more closely connected than supposed by Professor Kowalevsky in his memoirs on the *Hyopotamidæ*. The dimensions of the least worn of the two teeth are as follows:—

Length	·8
Breadth	·89
Height of crown	·45

The genus *Hyopotamus* in Europe ranges from the Upper Eocene to the Lower Miocene; in Sind it is obtained from beds which immediately overlie strata of Upper Miocene age.

NEW GENUS OF MERYCOPOTAMOID.

A large and complete upper molar tooth, scarcely touched by wear, is among Mr. Blanford's collection, which belongs to the same type of teeth as those of *Merycopotamus*, but which cannot be referred to this or any other known genus. The tooth carries four crescentoid columns on the masticating surface, which are relatively higher than those of *Merycopotamus;* the general form of these columns is the same as in the latter genus, with one important exception, which is that the external surfaces of the outer pair of columns are simply concave; they lack both the bold median ridge and the reflected anterior and posterior borders which characterise the teeth of *Merycopotamus;* the tooth has a well marked cingulum, as in the latter genus. The dimensions of the specimen are as follows:—

Length	1·13
Breadth	1·1
Height of crown	·81

I hope that additional specimens will be forthcoming to further elucidate the affinities of this specimen.

ANTHRACOTHERIUM PUNJABIENSE, *n. sp. nobis.*

Among a large collection of teeth collected in the Siwaliks of the Punjab by Mr. Theobald during last year, I have lately discovered a portion of a lower jaw which undoubtedly belongs to the above genus. The discovery of this genus, like *Hyopotamus* in the Siwaliks, is very remarkable, if the specimen has been obtained from the same horizon as that from which the majority of fossils come, since in Europe the genus is not found in strata newer than the Lower Miocene. It is, however, quite possible in this case, though not in the case of *Hyopotamus*, that the specimen may have been obtained from a lower zone in the Siwaliks than the one which yields the majority of vertebrate fossils: the greater number of the specimens obtained from these deposits are either gathered from the washed-out debris of the rocks by native collectors, or obtained by them from the villagers. If the specimen is from the normal fossiliferous zone, it affords another instance how in one region a genus may live down to a very much later period of time than in another; and so how the faunas of what are two distinct periods in one region may all appear in the same period in another region.

The specimen in question consists of the hinder portion of a right ramus of the mandible, containing the two last molars. The inner columns of the barrels of these teeth are approximately conical (bunodont), while the outer columns are concave internally (selenodont); the anterior extremity of the hindmost outer column joins a process from the inner column, so that the intermediate hollow is closed anteriorly and open posteriorly; the last molar has a large talon-column which is concave anteriorly, and which gives off a central process to join the postero-external column. The teeth are almost identical in general form

with those of the European *A. magnum*, but are of very much smaller size (they are unlike those of the smaller species from Rochette). The dimensions of the specimen are as follows:—

	Inch.
Length of last molar	·92
Width of ditto	·44
Length of penultimate molars	·6
Width of ditto	·42
Depth of jaw (broken)	·95
Thickness of ditto	·5

Although these teeth belonged to an animal of about the same size as *Chœromeryx*, they cannot be referred to that genus, as they present no generic points of difference from the teeth of the European species of *Anthracotherium*, which we should expect to occur in the lower molars of *Chœromeryx*. The only other mention of *Anthracotherium* among Indian Tertiary Mammalia is given in Dr. Falconer's paper on the Perim Island fossils (Palæontological Memoirs, Vol. I, p. 395), where certain teeth sent to the Asiatic Society of Bengal were doubtfully referred by the late Mr. James Prinsep to the genus *Anthracotherium;* I have no means of knowing whether or not this identification was correct, as the specimens seem to have been lost.

Since publishing some notes on the osteology of the allied genus *Merycopotamus*, in the ninth volume of the Records of the Geological Survey of India (page 144), I have had the opportunity of seeing a table of descent of the genera of the Ungulata published by Professor Kowalevsky in the twelfth volume of the German "Palæontographica," after the perusal of which I am led to make a few additional remarks on the affinities of the genus *Merycopotamus* and its allies.

In a table which I have published in the "Palæontologia Indica" (Ser. X—2, Vol. I—2, p. 60), I have placed the genus *Merycopotamus* provisionally in the family *Anthracotheridæ*, remarking that the genus presents points of affinity in the form of its teeth (selenodont) to *Anthracotherium* and *Hyopotamus*, and in the form of its lower jaw to *Hippopotamus;* the same conclusion was intended to have been given in the above-quoted paper for the Records, only by an unfortunate slip the words *Hippopotamidæ* and *Anthracotheridæ* have been transposed in the twelfth line from the bottom of page 153. The close connection of *Merycopotamus* with *Hippopotamus* is noticed by Professor Huxley, who states in his "Anatomy of Vertebrated Animals" (Ed. 1871, p. 375) that this animal "appears to have been a Hippopotamid, with upper molars having a quadri-crescentic, ruminant-like pattern."

Reverting now to Professor Kowalevsky's table of affinity, we find that the genera *Anthracotherium*, *Hyopotamus*, and their allies, are supposed to have taken their origin from some more generalised type of Hyopotamoid animals in the lower Eocene period, which common stock also gave origin to the more modern group of Ruminants. At this lower Eocene period, according to Professor Kowalevsky, the primitive Artiodactyla (*Paridigitata*) had already differentiated into the two groups of *Selenodonta* and *Bunodonta*, the early hyopotamoids being a lateral off-shoot of the first group; these two groups have since that time pursued separate courses of evolution, and have had no connection one with the other. The genus *Hippopotamus* took origin from a lateral off-shoot of the Bunodonta; this genus, therefore, which has a typical bunodont dentition, can have had no direct connection with the Hyopotamoid stock since the early Eocene period.

The genus *Merycopotamus* is not introduced into Professor Kowalevsky's table; there can, however, be no doubt but that since its teeth are very markedly selenodont, the genus would be placed somewhere near the *Anthracotheridæ* (or *Hyopotamidæ*, for the family is known by both names) and entirely apart from the *Hippopotamidæ*. In his Memoir on the Osteology of the *Hyopotamidæ*, published in the "Philosophical Transactions" for 1873, Professor Kowalevsky refers to the genus *Merycopotamus* at page 25 as belonging to a group nearly related to *Hyopotamus*, though it seems probable that the Professor would place the two genera in distinct families, owing to the upper molars of the Indian genus having only four cusps or cones on the masticating surface, while those of the European genera carry five. Whatever be the exact family position of the Indian genus, it is perfectly clear that according to Kowalevsky's plan of evolution there can have been no connection between the original stocks of *Hippopotamus* and *Merycopotamus* since the lower Eocene period.

I have already noticed in my former paper the very remarkable similarity in the form of the mandibles of *Hippopotamus* and *Merycopotamus*; and I think every one must admit that these two genera must have descended from some common ancestor which had a somewhat similarly shaped mandible. Now, neither of these two genera is known in the fossil state from strata older than the Siwalik period; while no other Pig-like animal, either recent or fossil, has a similarly shaped lower jaw, though there is a very slight rudiment of the descending process in the American Peccari and *Hyopotamus*; it is further a very noteworthy fact, that the lower jaw of the Siwalik *Hippopotamus* (as is well shewn in Pl. 61 of the "Fauna Antiqua Sivalensis") which is the oldest known species of the genus, is very much more like that of *Merycopotamus* than is the lower jaw of the living species; indeed, except in the matter of size and of the form of the teeth, the jaws of the two Indian forms are almost indistinguishable. If the common ancestor of these two genera had lived as far back as the lower Eocene period, it is extremely strange that the remarkable configuration of the lower jaw should have persisted in these two isolated genera up to the Siwalik period, and that there are no traces of any fossil forms with similarly shaped lower jaws which lived between the Eocene and Siwalik periods; it is therefore probable that the hypothetical ancestor of these two genera lived subsequently to the Eocene period; and that the Bunodonta and Selenodonta are more closely connected than Kowalevsky supposes.

With regard to this hypothetical ancestor, we may notice that *Merycopotamus* exhibits such affinities to the older Hyopotamoids of Europe, now known for the first time in India, that it is almost certain that the ancestral form must have been selenodont or hemi-selenodont, and that, consequently, *Hippopotamus* is descended from a selenodont and not from a bunodont ancestor. In favour of this view we may note the very significant fact that, in tracing back the affinities of *Hippopotamus*, Professor Kowalevsky has not been able to place a single genus between it and the primitive bunodonts of the early Eocene. If this view be true, the bunodont teeth of *Hippopotamus* are an instance of reversion to an older type; in confirmation of this view we may notice that the pig-like animals with selenodont teeth, like *Merycopotamus*, *Hyopotamus* and *Oreodon*, have all disappeared from the earth, and evidently belonged to a type which was not suitable to persist in that condition; this type is admitted to have been modified into the true Ruminants, and it is quite likely that another branch of it may have reverted to the bunodont type. It seems to be probable that the more specialised selenodont type of tooth, though advantageous to the true Ruminants, was not suitable to those animals which retained the general organisation of the Pigs, and that these animals either were further modi-

fied into more specialised groups, or died out, or reverted to the more generalised bunodont type.

The resemblance in structure between *Hippopotamus* and *Merycopotamus*, whether the above explanation be fully accepted or not, clearly points to some closer connection between the *Selenodonta* and *Bunodonta* than appears from Kowalevsky's table. In that table the term *Bunodonta* is used as equivalent to the *Suina;* but it appears to me much more natural to use the latter term in its older and wider sense as comprehending the pigs, the hippopotamoids, the hyopotamoids, and the anoplotherioids, since all these animals are related in many essential parts of structure; the two former groups will belong to the smaller division of *Suina Bunodonta*, and the two latter to the second similar group of *Suina Selenodonta;* from which latter the more specialised *Selenodonta* have been developed as a lateral off-shoot.

HIPPOPOTAMODON SIVALENSE, *n. gen.*, *nobis.*

The specimen for which I propose the above new generic name consists of a portion of a left maxilla of an animal allied to *Hippopotamus*, but which cannot be referred to that or any other known genus. The specimen has been for some time in the Indian Museum, and was collected by Mr. Theobald near the village of Asnot, in the Punjab, from upper Siwalik strata. The fragment shows the commencement of the zygomatic arch, and some portion of one-half of the palate; two nearly complete teeth, and a fragment of a third are preserved. The three teeth appear to be the three true molars; the last of these, being the most complete, is here selected for description.

This tooth has a nearly square crown, which is produced into four cones or columns, one placed at each angle; these columns are separated by a deep but narrow cruciform valley; between the four chief columns there is a small fifth column; while still smaller accessory columns occupy each of the four outer extremities of the cruciform valley; a crenulated cingulum occupies the fore and aft extremities of the crown. The main columns are semi-cylindrical in shape, and have infoldings of enamel from in front and behind, so that their worn dentine surfaces have somewhat of a trefoil shape, though this is not so marked as in *Hippopotamus*. The last tooth is placed immediately below the anterior root of the zygoma, as in the pig. The dimensions of the two last molars are as follows:—

Length of last molar	1·4
Breadth of ditto	1·29
Height of crown of last molar	·7
Length of penultimate molar	1·1
Breadth of ditto	1·05

The teeth are nearest to those of *Hippopotamus*, but are distinguished by the presence of the central fifth column, by the relative size of the other four accessory columns, by the crown being much lower, by the greater depth of the transverse valley, which extends to the base of the crown, by the form of the worn dentine surfaces, and of the cingulum, and lastly, by the position of the ultimate molar below the anterior zygomatic root.

The teeth of this new genus have no close resemblance to the molars of *Tetraconodon;* those of the latter genus, among other distinctive points, have wide open valleys, cylindriform columns, and no cingulum.

PERISSODACTYLA.

HIPPOTHERIUM THEOBALDI, *nobis*.

olim: SIVALHIPPUS.

In the last number of the "Records" (p. 31) I described a maxilla of a species of horse from the Siwaliks, which I then thought necessary to refer to a new genus, and for which I accordingly proposed the name of *Sivalhippus;* I now find that the specimen must probably be referred to *Hippotherium,* though it presents certain abnormalities which will perhaps subsequently render it necessary to make it sub-generically distinct, in which case the term *Sivalhippus* may be retained for the sub-genus.

In referring the specimen to a new genus, I was led to believe that the four protruded teeth belonged to the premolar series, in which case they would be exceedingly different from those of *Hippotherium;* I now find, after removing some more matrix, that the teeth must belong to the milk-molar series, in which case they are like those of *Hippotherium* in form, though they differ in the rate of succession.

I was led to consider the four teeth as premolars and not milk-molars, because they have only just come into wear, and yet behind them there is the alveolus of a fifth tooth, which must have been protruded from the jaw; now, in other horses, this fifth tooth, or first true molar, would not have pierced the jaw until the milk-molars had been considerably worn down, and until their vertical successors were visible in the jaw above them, which is not the case in the present specimen; on the supposition, however, that the visible teeth are premolars, the first molar must have been more worn than they, and must have left a disc of pressure against the last of the first series. I now find after further clearing, that the last protruded tooth of the specimen does not exhibit any disc of pressure behind, and that, consequently, the fifth tooth, or first molar, could not have been in use, but had merely cut the gum; this tooth was therefore newer than the first four teeth, which must consequently be milk-molars, and not premolars as at first supposed.

From the above explanation it will be evident that this species of *Hippotherium* differs from the true Horses, and, as far as I can gather, from other species of the genus, by the unusually early period at which the first true molar appears,—almost as soon as the milk-molars are touched by wear and before their vertical successors have shewn in the maxilla. In the genus *Equus* the first true molar does not appear until between the eleventh and thirteenth month, when the milk-molars have been greatly worn down, and when their roots have been to a great extent absorbed by the premolars.

The teeth of the present specimen are too large to belong to the milk dentition of *H. antilopinum,* but they may probably be referred to the larger Siwalik species, which H. von Meyer identified with the European *H. gracile,* but which I have found, as already stated in my last paper, to differ somewhat from the European species in the form of its upper permanent molar series; this larger species will, therefore, now be known as *H. theobaldi.* The rate of succession of the dental series, together with the unusually large size of the lachrymal depression in the adolescent maxilla, sufficiently distinguish the species from the European *H. gracile.* The Indian Museum also possesses specimens of the first median phalange of the foot of this species, which is extremely different from the corresponding bone in the European species, or in the smaller Indian *H. antilopinum;* there is, therefore, no doubt of the very aberrant nature of the larger Indian species, though from the resemblance of its upper molars to those of typical forms, I think it best for the present to retain it in the genus *Hippotherium,* and to drop the proposed name of *Sivalhippus;* the question will be more fully discussed on a subsequent occasion.

PROBOSCIDIA.

MASTODON (TRILOPHODON) *sp. nov. ?*

No species of Trilophodont *Mastodon* has hitherto been known from the Siwaliks, though one species—*M. pandionis*—has been found in the Deccan. I have now to announce the presence of a species in the Siwaliks; this species is known by two lower molar teeth, one of which is the last milk-molar, and the other is the penultimate true molar. Both specimens were collected last year by Mr. Theobald from the Siwaliks of the Punjab.

Each of these teeth carries three transverse ridges and a fore and aft talon; the presence of only three ridges on their teeth shews that they cannot belong to either of the two Indian Tetralophodont *Mastodons* (*M. latidens* and *M. perimensis*) or to the aberrant Pentalophodont *M. sivalensis;* in the first of these groups only the very small second milk-molar is trilophodont, while in the second group only the first, and perhaps the second, milk-molars are trilophodont.

Both the present specimens belong to the wide-toothed *Mastodons;* the ridges are divided by an antero-posterior median valley; the first two pairs of columns are placed in the same transverse line, but the third pair are placed somewhat unsymmetrically; there is a large quantity of cement in the valleys, which of itself would be a sufficient distinction from the other Indian species: the transverse valleys are fairly open. The length of the larger specimen is 6·8 inches, and its breadth 3·7 inches: the length of the last milk-molar is 4·1 inches, and its breadth 2·4 inches.

The teeth have not the complex crowns of the Trilophodont *Mastodon pandionis;* it is therefore quite clear that they are distinct from all other Indian species of the genus; I believe they are also distinct from any European species. If the latter should prove to be the case, I should propose to call the present species by the name of *Mastodon (Trilophodon) Falconeri* in honor of the describer of the many other forms of extinct Indian Proboscidia.

CARNIVORA.

PSEUDÆLURUS SIVALENSIS, *n. sp.*

Mr. Theobald's Siwalik collection from the Punjab contains one-half of a lower jaw of a Feline animal with four pre-molars which consequently belongs to this genus; the specimen belonged to an animal of about the size of a small Leopard. The carnassial tooth is of the normal Feline type: only two other specimens of the genus *Pseudælurus* are known, one from the Miocene of Sansans, and the other from the Pliocene of Nebraska. Both species are distinguished by their size from the present specimen. The dimensions of the specimen are as follows:—

Length of jaw (broken)	3·5	Thickness	·5
Depth	·8	Length of alveolus of canine ..	·75

AMPHICYON PALÆINDICUS, *nobis.*

The only remains of this species hitherto known are an upper tubercular molar, and a lower carnassial, one from Kushalghar, and the other from Nurpur. These specimens are figured on Pl. 7 of "Indian Tertiary and Post-Tertiary Vertebrata."* Mr. Blanford has sent from Sind the anterior half of a right lower carnassial, which exactly corresponds with the Nurpur specimen, and which shows that the species extended its range into the Sind area.

* Palæontologia Indica, Ser. X—2, Vol. I—2.

NOTE ON THE ARVALI SERIES IN NORTH-EASTERN RAJPUTANA, *by* C. A. HACKET,
Geological Survey of India.

The rocks that have been named the Arvali Series cover a large area in Rajputana. The portion of them which has been examined, and of which the following is a brief description, lies in the territories of the Rajahs of Alwar, Jaipur, Bhartpur and Karauli, included between Bhartpur on the east and Jaipur on the west, the northern boundary of the Alwar territory on the north, and a line drawn in a south-westerly direction from Byana through Karauli to the fort of Rimtumbour on the south.

This area is occupied by ranges of hills, the highest of which rise to an elevation of upwards of 2,500 feet above the level of the sea, and about 1,600 feet above the general level of the surrounding country formed of wide sandy alluvial plains. Some of these hills are narrow ridges; others form considerable masses, occasionally flat-topped, presenting arid, stony plateaux several square miles in extent. The principal of these hill-groups are those of Alwar, Byana, Lalsot and Rimtumbour.

The Alwar hills are in places twenty miles across; they are, however, intersected by narrow longitudinal valleys having the same general direction as the hills themselves; both, in fact, following the strike of the rocks.

The direction of the ranges varies considerably; the most general direction is north to south and north-east to south-west, but in places the ridges describe a complete semicircle.

The principal rivers draining this area are the Moril, Banas, Sabi and Banganga. The two former fall into the Chambal near Rimtumbour, and the two latter into the Jumna, one near Delhi and the other below Agra. Their broad, shallow sandy beds, sometimes upwards of a mile wide, contain little or no water, except in the rains.

In the accompanying map, on account of its small scale, the hill-shading has been omitted.

Besides the Arvali series, there are in our area a gneiss and a schist series, the Gwalior and the Vindhyan series.

The gneiss is confined to a few small isolated hills on the plain, and some outcrops at the base of the scarps of the Arvali rocks on both sides of the Banganga valley; but in the latter position it is very imperfectly seen, as it is mostly covered by the debris of the overlying rocks.

The schist series is exposed in several places in the Byana hills and at Malarna near the Moril river. In the Byana hills at Nithahar, the schists consist of alternations of mica-schists and thin bands of quartzites; they are nearly vertical, and are overlaid unconformably by the rocks of the Arvali series.

Both the Gwalior and the Vindhyan series have already been described, the former in the Records and the latter in the Memoirs of the Survey.

The Gwalior series is represented in our area in the ridge at Hindun, extending in a north-east to south-west direction, and formed of banded red jasper alternating with bands of hæmatite.

The Vindhyan series is represented by a few outlying hills which occur west of a line of fault forming the north-western boundary of the main basin of the series.

Arvali series.

The rocks of the Arvali series are much disturbed, seldom dipping at a lower angle than 70°; their most general strike varies from north—south to north-east—south-west; but in places they describe nearly three-fourths

of a circle. In the Alwar territory, where more extensive and continuous sections are exposed than elsewhere within our area, the rocks are folded up and repeated many times; thus, a short distance north of the Banganga river the same beds are repeated at least a dozen times in a section sixty miles long. The rocks have undergone a considerable amount of metamorphism, some of the quartzites being compact and vitreous, the limestones highly crystallised and full of minerals, such as shorl, actinolite, tremolite, &c., and the schists and slates highly mineralised, containing an abundance of crystals of andalusite, staurotide, garnets, &c. An arkose rock, or pseudo-gneiss, locally forming the base of the series, is often so highly metamorphosed as to render it difficult, in places where good junction-sections are not exposed, to tell it from the older gneiss upon which it rests.

A great variety of rocks is included in the series, the principal of which are quartzites, dolomitic limestone, contemporaneous trap, hornstone-breccia, schists and slates.

These have been grouped in the following manner, in descending order:—

Mandan—slates, schists, quartzites.
Ajabgarh—slates, quartzites, hornstone-breccia, limestone.
Alwar—quartzite, conglomerate, schists, limestone, bedded trap.

The Alwar group has been sub-divided in descending order into—

Alwar group.

Alwar quartzites, including irregular bands of schists, conglomerate and contemporaneous trap,
Raialo limestone,
" quartzite.

The lowest beds, the Raialo quartzite and limestone, are only seen near the southern extremity of the Alwar hills north of the Banganga river. In the three bays of Andhi, Bhangarh and Baswa, the quartzite, compact in texture, regularly bedded, and grey in color, rests upon the gneiss and dips under the limestone.

The limestone is highly crystallised and dolomitic, and abounds in tremolite, shorl and actinolite; it is often pure white, but marbles of a great variety of color and also of texture can be obtained. There are large spreads of the limestone at Raialo and Baldeogarh and at Kho; in other places, as west of Andhi and in the Baswa bay, the thickness is considerably less. No good sections of the junction between the Raialo quartzites and the gneiss are exposed, although the two are often seen within a few yards of each other; the actual junctions are all covered by the debris.

Both the Raialo quartzite and limestone are locally overlapped by the next higher member of the group, the Alwar quartzite, which then rests directly on the gneiss. A few good sections of the junctions are exposed, which shew that the Arvali series is quite unconformable to the gneiss. The Alwar quartzite is the most prominent member of the whole series, both from the extent of ground it covers, and from the highest and largest groups of hills being formed of it; also from the principal forts in the neighbourhood, those of Byana, Alwar and Rimtumbour being built on it.

The thickness of the Alwar quartzites varies considerably in different sections; thus, in the Byana hills an enormous thickness of them is exposed in an unbroken section upwards of five miles long in which the rocks have a steady dip to the north of about 20°; but about Nithahar the lower beds die out and the quartzites are reduced to a few hundred feet. In the Lalsot hills, where the rocks dip at a much higher angle, the quartzites are in force. In the Alwar hills, too, there is in places a great thickness, but they thin out to a few hundred feet in a southerly direction.

The quartzites are mostly light grey in color, regularly bedded and compact in texture, although coarser beds are of frequent occurrence. They also include, especially in the

Byana hills, thick bands of conglomerate. Ripple-markings and sun-cracks are common and are particularly well seen in the Alwar fort hill. An arkose is of frequent occurrence at the base of the Alwar quartzites, where they rest upon the gneiss.

The best section of the junction of the Alwar quartzites and the gneiss is exposed near Tatra. South of the road leading to Tatra the granitic gneiss occurs at the base of the ridge, and upon this rests a regularly bedded coarse quartzite dipping at a high angle to the west. North of the road some additional beds come in between the gneiss and the quartzites. Resting directly on the gneiss is a band of conglomerate about two feet thick, composed principally of rolled pebbles of quartz; upon this there is a considerable thickness of the arkose, the materials of which were apparently derived from the gneiss; this passes up gradually into the ordinary quartzites of the series. Other sections shewing the unconformity between the two series are exposed near Garhi a few miles east of Tatra, and near the southern end of the Tatra ridge at Sabraoli, as well as in the Lalsot hills at Geesgarh.

In places the arkose rock has been re-metamorphosed to such an extent that when not seen in connection with the gneiss below, or the quartzites above, it is difficult to tell it from the true gneiss. Instances of this occur in the hills round Harsora, which are formed of obscurely bedded gneiss, but from their being isolated on the plain (the only rock near is a ridge of quartzite about half a mile to the south) I am unable to say to which series they belong. At Dodikar, a few miles north-west of the town of Alwar, where the arkose rocks are well developed, they form a circle of hills, in the centre of which the rocks are covered by the alluvium, blown sand, &c. The arkose at the base of the hills is highly crystalline and as gneissose as that of the Harsora hills, but here they pass up gradually into the quartzites which cover them. Other sections of the arkose rocks passing into the quartzites are met with at Palpar, Baggeri, Khertal and Pahari.

The best sections of the Alwar quartzite are to be seen in the Byana hills, where an enormous thickness of them is exposed, as they are less disturbed and altered than elsewhere, for although they are a good deal twisted along the strike, they scarcely ever dip at a higher angle than 20°. At Byana the strike is north-east to south-west; but at Badalgarh, a short distance west, it changes to west-north-west, east-south-east; and at Hathoree, about twelve miles further west, it again becomes north-east to south-west.

In these hills the lowest members of the Alwar group (the Raialo quartzite and limestone) are absent, and the group consists principally of quartzites, shales, thick bands of conglomerate, and contemporaneous trap. Overlap occurs among the quartzites, and there are two cases of local unconformity.

The Alwar group in the Byana hills rests unconformably upon the schist series. The unconformity can be well seen at Nithahar, where the quartzites rest upon the edges of the nearly vertical schists, consisting of alternations of argillaceous and quartz schists, and with a thin band of conglomerate seldom more than a foot thick between them. Other sections of the unconformity are exposed a few miles further west.

The Alwar quartzites in these hills can be divided into several sub-groups well marked by overlap or local unconformity:

Weir—quartzites and black slatey shales.
Damdama—quartzites and conglomerate.
Byana—white quartzite and conglomerate.
Badalgarh—quartzite and shale.
Nithahar—quartzites and bedded trap.

The middle sub-groups attain to an enormous thickness at the eastern end of the hills, but die out near Hathoree. At the western end, a few miles south-west of Nithahar, all the lower sub-groups are overlapped by the highest, which then rests upon the schists. The lowest of these sub-groups, the Nithahar, consists of upwards of 2,000 feet of quartzites, including several bands of contemporaneous trap. The next sub-group, the Badalgarh, consists of about 800 feet of shales and quartzite, best seen in the Badalgarh fort hill, but west of this it gradually thins and dies out near Seta.

The Byana sub-group is formed of a white quartzite containing many bands of conglomerate. It extends from Byana some miles west, but dies out three or four miles east of Seta. These conglomerate bands are well seen in the hills near Byana. They vary in thickness from 1 to 20 feet, divided by thin bands of quartzite. They are made up of pebbles of quartzite, very similar to those of the lower sub-groups. All of the conglomerate bands die out within a quarter of a mile of Byana. Above the Byana comes the Damdama sub-group, composed of an enormous thickness of conglomerate and quartzite. The conglomerate is made up of pebbles of quartzite, jasper, and white quartz, all more or less water-worn. Like the other sub-groups, this thins out very rapidly. At Hathoree, where the strike of the rocks suddenly changes, it is reduced to a few feet; it expands again a short distance further south-west, but is eventually overlapped a few miles south of Nithahar by the highest sub-group, the Weir.

In a gorge about one and a half miles east of Seta, the Damdama sub-group for a short distance rests upon a denuded surface of the Badalgarh sub-group; further west the latter sub-group dies out and the Damdama rests unconformably on the Nithahar sub-group. These unconformities appear to be local, for to the east of Seta, where good sections of the junctions of the different sub-groups are exposed, no trace of unconformity could be detected.

The highest sub-group, the Weir, consists of black slaty shales, and a great thickness of quartzites. It occupies the broken east and west ridge a short distance north of the Byana hills. At Hathoree the strike changes to south-west, and at two or three miles south-west of Nithahar it overlaps all the other sub-groups and rests upon the schists. This ridge of Weirs continues in a south-west direction and connects the Byana with the Lalsot hills, where there is again an enormous thickness of the Alwar quartzites in which presumably all the sub-groups are represented, but are not distinguishable, as all the conglomerates have disappeared. In the Alwar hills, too, these sub-groups cannot be traced, although there is an equally great thickness of the quartzites, including several thin bands of conglomerate, but which are very irregular, continuing only a short distance along the strike.

The Arvalis along their south-eastern boundary, between Karauli and the Banas river, form two synclinals in which both the Alwar quartzites and the lower portion of the Ajabgarh groups are exposed. South-west of the Banas a considerable thickness of the Alwar quartzites, including two or three bands of trap, is seen in a shallow synclinal in the Rimtumbour hills.

This boundary of the Arvalis is formed by a fault, on the south-eastern side of which the top group of the Vindhyans is brought against the Alwar quartzites. In the two synclinals between Karauli and the Banas river, on the north-west side of the fault, are several ranges and hills formed of shales and sandstone, probably the representatives of lower members of the Vindhyan series.

Ajabgarh group.

The rocks of this group occur chiefly in the Alwar hills; but a small thickness of them is also exposed in the Rimtumbour hills. In the Alwar hills they occupy the synclinal trough in the quartzites of the Alwar group; they also form the ridges to the east of the town of Alwar. The group contains a consider-

able thickness and a great variety of rocks, the principal of which are limestone, quartzites, hornstone-breccia, and slates.

The lowest member of the group is a thick band of limestone called the Kushalgarh limestone. It is generally compact in texture, dark and light blue in color, the two shades arranged in alternate bands, and frequently contains an abundance of schorl, actinolite, and tremolite. The hornstone-breccia is generally found on the top of the Kushalgarh limestone, but is frequently absent. Above this there is a band of quartzite, upon which rests a considerable thickness of black slates frequently containing garnets and andalusite, capped by a quartzite, the Berla quartzite.

So far the section of the Ajabgarh group is continuous in the valleys; but the upper rocks, being only exposed in the isolated ridges east of Alwar, are difficult to place in the section. The ridge extending from the Motidongri hill, close to Alwar, composed of alternations of calcareous and quartzite bands, is clearly higher in the section than the Berla quartzite; and the Goleta ridge, about six miles east of Alwar, is probably still higher in the section.

The best sections of the lowest beds of this group are exposed in the Kushalgarh and Ajabgarh valleys. In the former, from the town of Kushalgarh to the mouth of the valley at Talbrich, the whole of the bottom of the valley, in places upwards of a mile wide, is occupied by the Kushalgarh limestone. Higher up the valley, rocks higher in the section come in. Both the breccia and quartzite are poorly represented, but the black slates are well developed and include thin and irregular bands of limestone as well as one or two bands of hornblende rock.

A thicker section of the Ajabgarh group is exposed in the Ajabgarh valley. The Kushalgarh limestone resting upon the Alwar quartzites is seen on both sides, dipping towards the centre of the valley, though not so continuously on the west as on the east side. The hornstone-breccia and the quartzites above appear to be very irregularly developed in this valley. The breccia is nearly continuous on the west side, and there is but little of the quartzite, but on the east side, particularly at the northern end, a considerable thickness of the quartzites, but little of the breccia, is seen. The whole of the centre of the valley is occupied by the black slates. These rocks extend into the Narainpur valley as far as Gazeka Thana; but north of that there are only a few small hills of slates in the centre, and some of the limestone and breccia on either side of the valley. The remainder is covered by the alluvium.

In the Delawas valley, patches of the Kushalgarh limestone are exposed on both sides of the valley; the higher rocks occupying the centre are covered by the alluvium. Near Sillisur, about four miles south-west of Alwar, the hornstone-breccia above the limestone is exposed. It is in some places obscurely bedded, but it generally occurs in great masses devoid of any structure. It sometimes contains large pebbles of quartzite; this is the case at the southern end of the Sillisur lake, where it is largely developed.

The eastern edge of the Alwar quartzites at Alwar, and for a long way south, dips at an angle of about 80° to the east under a broken section of the Ajabgarh group, here represented by a few hillocks of the Kushalgarh limestone and breccia and the overlying quartzites. The slates are entirely covered by the alluvium which extends to the Motidongri ridge, formed of nearly the highest member of the group.

Of the ridges to the east of the Motidongri ridge many are formed of the rocks of the Ajabgarh group. Thus, in the hills forming a broken circle a few miles east of Alwar, in the centre there is a hill of the Alwar quartzites dipping in all directions towards the edge of the circle and under the encircling ridge of the Ajabgarh rocks consisting, on the

eastern side, of the black quartzites and slates in which crystals of andalusite are abundant. The rocks on the western side are higher in the section. At Loharwarri there is a black limestone, probably the same as that in the Motidongri ridge, and over it a considerable thickness of a rough blue quartzite, largely quarried for grindstones. Between the centre hill and the ridge are some hillocks formed of the Kushalgarh limestone and breccia.

The four ridges east of Malakheri, something in the shape of an inverted W, form a double anticlinal in which the Ajabgarh rocks are well represented. In the centre of the western anticlinal there is a large hill of the Alwar quartzites dipping under the Kushalgarh limestone and breccia on three sides, *viz.*, north, east, and west, above which come the black slates with a band of talcose limestone near the base and covered by the Berla quartzite, of which the greater portion of the four ridges is formed. This quartzite requires notice, as it makes a splendid building stone and is largely quarried for that purpose; it is pearly-grey in color and contains numerous specks of a black mineral, probably hornblende. In the eastern anticlinal a similar section is exposed, with the exception of the Alwar quartzites in the centre. The western limb of the double anticlinal extends in a northerly direction as far as Noganwa, where the Alwar quartzites of the Tigara ridge dip under it; and in a south-westerly direction, to some miles beyond the Deoti lake in a synclinal trough of the Alwar quartzites.

The Mándán group.

The rocks of this group occur only in the Alwar territory, principally in the north-west corner of the State, on the left bank of the Sahi river at Mándán Barod and Tasing, and at Mandaor, thirty miles to the south-east of Alwar. The group consists of schists and slates, abounding in crystals of andalusite, staurotide, garnets and actinolite, and some thin bands of quartzite interbedded with them.

There is some doubt as to the position of these rocks in the series, or even if they belong to the series at all. This doubt arises from their occurring in isolated ridges disconnected from any known rock of the series. Near Barod, however, there is a long hill formed of the Kushalgarh limestone and breccia, between two ridges of the schists, and separated from them by about half a mile of alluvium.

Again, at Mandaor, the double ridge of Mándán schists occurs between two ridges of Alwar quartzites, converging towards the south and both dipping towards the schists, apparently forming a synclinal in which the schists lie. Mineralogically there is little difference between the Mándán rocks and those of the known Arvali series; the Ajabgarh slates containing andalusite, &c., in the hill east of Alwar, as well as the quartzites, are very similar to those of the Mándán group; so that it seems probable that the Mándán rocks really belong to the series, and if so they form the highest group here represented.

Trap.

The lower part of the Alwar quartzites contains numerous bands of contemporaneous trap, some of them of considerable thickness and forming hills several hundred feet high. In some sections they are very numerous, while in others they are altogether absent. In the Byana hills there are at least six bands separated by bands of quartzite. At the southern part of the Alwar hills, for some miles round Tehla and north of Raialo, they are also very numerous. In the Tehla section there are at least ten separate bands. Again, in the Rimtumbour hills the quartzites include several bands of trap, one of which is upwards of 150 feet thick. In the northern part of the Alwar hills a comparatively thin band of trap is occasionally met with, but generally it is altogether absent. In the large accumulations of quartzites in the hills west of Rajgarh, and also in the Lalsot hills, there is no trap in the section.

Many of these bands of trap can be traced for several miles; this is particularly the case with those west and north-west of Raialo, and also in the Rimtumbour hills; but in other places, as near Tehla, they often die out very suddenly. Occurring on nearly the same geological horizon as these traps are some bands of hornblende rock, which are probably of metamorphic origin.

Relations of Arvalis to other formations.

The position of the Arvali series in the scale of Indian formations is somewhat doubtful. I have already stated that it rests unconformably upon the gneiss and the schists, and that outlying ridges and hills probably belonging to the Vindhyan series rest upon it. The doubtful point then, is the relative position of the Gwalior and the Arvali series.

The Gwalior series is most largely developed in the neighbourhood of Gwalior, where it rests unconformably upon the gneiss of Bundelkhand, and is covered, also unconformably, by the Vindhyans. The series there consists of a quartzite-sandstone at base, covered by many hundred feet of banded jasper, including several bands of limestone and contemporaneous trap. The rocks of the series are only slightly disturbed, seldom dipping at a higher angle than 5°, and are much less altered than the Arvali series in Rajputana.

The only representative of the Gwalior series within our area is a long broken ridge of banded jasper rocks dipping at an angle of between 60° and 80° to north-west near Hindon. The ridge runs in a north-east to south-west direction parallel to, and at a varying distance of 200 yards to two or three miles from, the north-west boundary of the main area of the Vindhyan series. The north-eastern extremity of this ridge extends to within three miles of the south-eastern end of the Byana hills formed of the Arvali series.

The only rocks seen in contact with the banded jasper of the Gwalior ridge at Hindon are some hills of quartzite sandstone associated with some red and black slaty shales and irregular bands of limestone. The quartzite sandstone is in places highly altered; but in others it shews scarcely any traces of alteration. It is nearly vertical, and the strike is roughly parallel to that of the banded jasper. All the junctions are concealed by debris; but the quartzite appears to rest upon different beds of the jasper rock; thus at the northern end of the ridge the quartzites are on the southern side, but further south they cross the ridge and are on the north-west side of it. From the position of these hills of quartzite sandstone, and from their being generally less altered than the rocks of the Arvali series, it seems probable that they are outliers of the Vindhyan series. On the other hand, the black and red slaty shales and limestone are unknown in the lowest beds of the Vindhyans; but somewhat similar beds occur in the quartzites of the Arvalis.

The only other evidence bearing upon this point is the presence of some jasper pebbles in the conglomerate beds of the Arvali series; but although these resemble the Gwalior jaspers, they are not sufficiently characteristic to determine the point. The question is one of much geological interest; it would greatly complicate matters to have to make the Arvalis younger than the Gwaliors.

Economic geology.

The useful minerals found within our area are—copper pyrites, rutile, argentiferous galena, manganese nickel, iron.

Several old copper workings exist, from which through a long series of years a considerable amount of ore has been extracted, but at the present time they are almost entirely abandoned. The natives say that some of the richest deposits of ore had to be abandoned in consequence of the influx of water. In other cases, the richest mines fell together, burying a number of miners, and have not since been re-opened.

The following is a list of the localities in which copper ore has been worked or traces of it observed:—

Daribo.	Baghani.
In the ridge to the west.	Pertabgarh.
Indawas.	North of Nitahar.
Bhangarh.	Near Garh in the Lalsot hills.
Tasing.	Lalsot.
Kushalgarh.	Nabaro.

The most important of these is Daribo in the Alwar territory. The mine is situate on a sharp anticlinal bend, in a thin band of black slates intercalated in the Alwar quartzites. Formerly the workings consisted of some small pits on the hill-side. Dr. Impey, then Political Agent at Alwar, had a long adit level driven into the hill to drain these pits. The level runs in a southerly direction parallel to the strike of the rocks. I could see no trace of a lode; the ore appears to be irregularly disseminated through the black slates, a few specks and stains only being seen in the quartzites. Where richer nests of ore were met with, the miners have extended their workings a short distance above or below the level. They state that a rich nest of ore occurs in a pit sunk below the level near its southern extremity, but that it had to be abandoned on account of the water.

The copper occurs in the form of pyrites mixed with arsenical iron. Small quantities of carbonate of copper were observed in the mine, probably the result of the decomposition of the sulphuret. The mine is now nearly abandoned, and but little ore is to be seen; I had some difficulty in finding a piece the size of a hazel-nut. I found traces of copper in some black slates on the same geological horizon in the ridge a short distance west of Daribo.

Near Indawas there is a long open cutting from 20 to 30 feet deep, from which copper ore has been extracted, but the workings are now filled with water. About a mile from these workings I found some miners engaged in sinking a small pit in the Kushalgarh limestone, from which they got a little ore. The Bhangarh workings consist of two or three small pits now fallen together. I found traces of copper in the Mándán schists near Tasing.

The workings at Kushalgarh, Baghani, and Pertabgarh have been abandoned for many years. The natives say that at the two latter places the workings were very extensive, and that the mines fell together suddenly, burying a large number of men. The workings near Nitahar, at Garh, Lalsot and Nabaro are very small, and have long since been abandoned.

A few years ago a small deposit of silver-lead ore was discovered in the Kushalgarh limestone near Gudha, and a pit was sunk in it; but after working for a short time it was found that the ore died out in every direction. The pit has now fallen together.

Rutile (titanic acid) exists in small quantities in some little quartz veins in the Motidongri ridge a short distance south of Alwar.

Iron and Manganese.

Iron ore occurs in large quantities at two places near the base of the Arvali series, one near Bhangarh and the other near Rajgarh. They supply the ore to a large number of furnaces in the State. Judging from the workings, an immense quantity of iron must have been produced from these mines. These excavations are several hundred yards long and, in places, 20 to 30 wide. They appear to be at an angle to the strike of the beds; but the rocks are so disturbed, and the junctions covered by debris, that I was not able to determine the point. The following is an analysis of the ore from Bhangarh: A mixture of limonite and magnetite and oxide of manganese, containing 59·67 per cent. of iron, and 12·7 of manganese. Large quantities of a superior iron ore have been raised from the Gwalior rocks in the ridge near Hindun.

Nickel.

When making inquiries for the mineral Saipurite (Jaipurite), a mineral of cobalt found in the Arvali series at the Ketree mines in Shekawattee, I was shewn a bit of iron and the ore from which it had been produced. The iron was used for cannon balls which flew into a number of fragments when fired. The ore came from the Bhangarh mine. On analysis both the iron and the ore were found to contain nickel, in the latter, however, only a trace. I tried to find the ore in sitê, but was not successful. I was shown the pit from which it had been taken, but it had fallen in.

Building materials.

Building materials, some of a very superior quality, are abundant. Limestone capable of making good lime exists in all parts of the Alwar hills, as well as in Karauli and on the Banas river.

The ordinary quartzite is a useful stone for rough buildings, walls, &c. But the Berla quartzite makes an excellent building stone. It is pearly-grey in color, very durable, not difficult to work and, easily quarried. It is largely quarried at Berla, Daroli, Bharkhol, &c.; and quarries of it could be opened in any part of the four ridges east of Malakheri. A large part of the Rajah's private station at Alwar is built of this stone.

Schistose quartzites used for roofing, flags, &c., are largely quarried near Rajgarh, Kirwari, Mándáu, and north of Amber. I have seen slabs of this rock nearly 20 feet long and 2 feet wide. The Mándán rock produces large, square, thin slabs.

Finely laminated argillaceous flags, splitting easily along the laminæ, are procured from some quarries at Salimpur at the end of the Alipur ridge near the Banganga river. Slabs of large size, and of any thickness down to half an inch, are quarried. The stone contains a good deal of iron pyrites, which discolors it when exposed to the weather.

The Ajabgarh slates have been used for roofing most of the stations on the railway. It is not quarried, that I know of, within our area, but some of the hills in the Ajabgarh valley would, I think, produce equally good slates.

A talcose limestone at the base of the black slates is used for ornamental purposes, such as carved door-posts, &c. It is a soft stone and easily carved.

The Raialo group produces fine marble. The Taj at Agra is, I believe, built of it. It is quarried at Raialo and Jheri; and the natives there are still very clever in making *jalee* or perforated screens. Colored marbles can be had near Kho and Baldeogarh, and black marble from the Motidongri ridge.

Good mill-stones are made from the blue quartzites of the Goleta ridge.

BORINGS FOR COAL IN INDIA, *by* THEODORE W. H. HUGHES, F. G. S., *Associate, Royal School of Mines. Geological Survey of India.*

The purpose of the present paper is to introduce a series of notices on borings for coal throughout India, which, it is hoped, will possess some interest and, possibly, be of practical utility to those whose duties are connected with this branch of mining engineering. The advantage of having in an accessible form, for purposes of comparison, statistics from different localities as to method of boring, progress of boring, cost of boring, &c., will, I trust, be appreciated by those interested in this matter, and in time acknowledged by a greater readiness on the part of individuals and associations to supply information than has as yet been evinced. Up to the present I am unable to quote beyond the experiences at the Government borings. Such as they are, they are here offered as measures of comparison.

The regions most carefully and most perseveringly explored within the last few years with the object of testing the occurrence of coal, its extent and its quality, have been those of the Wardha and Godávari valleys, and near or within the Sátpúra range of hills. Nearly 200 borings have been carried out. As a rule, few of them exceed 300 feet; but at Khappa, one, under the immediate charge of Mr. Stewart of the Public Works Department, has already attained a depth of 710 feet.

Method of boring.

The method of boring most generally practised is that of jumping the rods by the agency of a windlass that works a rope passing over a sheave fixed to a set of shear legs of sufficient height to allow of two lengths of rods to be unscrewed at once. In the Wardha valley, to which my own experience of boring operations is confined, a spring-pole or a lever was rarely employed; the single jack-roller or winch doing the duty of raising the rods at each stroke, the sudden slackening of the rope on the drum allowing them to fall again.

During the early stage of our explorations the attempt was made to secure the advantages supposed to accrue from the employment of steam-power; and a Mather and Platts' machine, under the charge of Mr. Mather's son, was for some time put upon its trial. The essential principle of Mather and Platt's system consists in the substitution of a flat rope for the iron rods employed in the ordinary methods, by which means a saving in time is effected in raising and lowering the cutting tools. In practice, however, it was found that for the shallow depths required for the holes in the Wardha valley, there was scarcely any appreciable saving in actual time of working. For deeper holes the steam borer would probably have answered, as then more scope would have been afforded for the display of those advantages which its system of working undoubtedly possesses. Shifting the machine was in each instance a tedious business, owing to the unfinished condition of the roads, and the consequent difficulty of procuring suitable carriage, and more time was lost at each removal than would have sufficed to put a shallow boring down by hand.

Size of holes.

The diameter of the holes varied from 5 to 3 inches. The larger of these dimensions was adopted at the outset, in order that better illustrative samples of the rocks passed through might be obtained than would have been procured from holes of the smaller size. When experience had familiarised the eye with the aspect of the debris characterising the respective horizons of productive and sterile measures, the diameter of the holes was diminished and with considerable advantage in respect to rapidity of sinking.

Cutting tools.

The usual form of cutting or chipping tool was the flat chisel or straight bit. It was found to be most generally useful, being applicable to almost all varieties of strata and being easily re-sharpened—a quality that cannot be too highly estimated in a country where considerations of petty repairs are of much moment. For penetrating extremely hard rock a V chisel was occasionally used. Against trap, however, it was of little more avail than the ordinary straight bit. For clearing the ribs or snags that resulted from imperfect manipulation, a + or a T chisel was used, but the latter is a precarious tool to trust in the hands of native workmen, as it requires careful management. One of the most important exploratory borings* in the Wardha field was lost by the jamming of a chisel of this form.

An objection sometimes urged against the claim of the straight bit to obvious superiority is the supposed necessity of employing a second chisel to round the hole. This need should not exist, if the chisel be continued upwards, for four or five inches, of the same

* Mángli.

breadth as the cutting edge. By adopting this plan of shaping, instead of allowing the smith to diminish the width of the tool throughout the length indicated, a smooth hole can be made at the same time that the chisel is advancing. For boring through stiff clays, an S chisel is a convenient form, as it penetrates less, if the drop be carelessly increased, than does the straight bit, and consequently is not so likely to stick. The auger is preferred by some.

Respecting the question, which is the most efficient pattern of tool for a given kind of work, I have remarked that a good deal depends upon the predilection of the workmen, and that the best results are attained by adhering to the form of chisel they have been first accustomed to handle. For general usefulness, however, there is little doubt that the straight bit claims pre-eminence. For stiff clays, I would recommend the S chisel, and for soft clays the auger. In moderately free sandstones and shales, the S chisel will do excellent work, and it may be used as a substitute for the straight bit. In the ordinary grits of the coal-measures it fails to make the same amount of way.

Cleaning tools.

To clean the hole, a pump or sludger provided with an ordinary flap-valve, or else a ball-valve, was employed. It possesses an advantage over the wimble and other revolving tools used for clearing, in that it may be lowered and raised by means of a rope, and the time occupied in connecting and disconnecting the rods is saved. The ball-valve is a very simple and convenient form of valve to adopt, as it does not get out of order, but the balance of general opinion is, I believe, in favor of the ordinary flap-valve.

Piping.

For most of the bore holes, only a few lengths of piping besides the guide tube were required. When the fear of any clay swelling arose, it was found well to push operations on without cessation, and to work night, as well as day, shifts. This usually obviated the necessity for lining. The most intractable rock was running sandstone, and experience proved that when the difficulty of keeping a hole was due to this cause, it was an economy of time and labor to shift to a fresh position if piping were not available.

Rate of progress.

The rate of progress varied according to the rocks to be bored through, trap being the most refractory and ordinary felspathic silicious sandstone the most easy to deal with. In a scale of tractability they stand in the following order—a wide difference of degree separating trap and ironstone from the rest:—

1. Trap.
2. Ironstone.
3. Vitreous quartzose sandstone.
4. Clay.
5. Coal.
6. Shale.
7. Ordinary sandstones.

Below will be found in tabular form the speed at which some of the holes in the Wardha Valley were put down, and the cost of cooly-labor divided over each foot or yard. There were usually three shifts of workmen in the 24 hours when the holes were being continuously pushed forward. Each shift consisted of twelve coolies and two mates or brace-head men as a rule, but sometimes an additional couple were put on, if the hole was a troublesome one, making sixteen men in all. The pay of the coolies was 4 annas a day, the pay of the mates 5 annas. An overseer on Rs. 25 to 35 a month looked after one and sometimes two bore holes.

The returns that I quote are those furnished to me by Mr. Ness and by Mr. Smyth. Each has adopted a form which I publish as received.

Statement of cost of bore holes at Warora for each 10 yards in depth.—Wardha Valley Coal-field.

	Depth of hole.	Number of days' boring.	Cost per yard of 1st 10 yards.	2nd 10 yards.	3rd 10 yards.	4th 10 yards.	5th 10 yards.	6th 10 yards.	7th 10 yards.	8th 10 yards.	9th 10 yards.	10th 10 yards.
			Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Bore hole O¹ ...	110'	5	0 12 9	1 9 6	2 6 3	3 3 0	...	...	...	...	...	...
„ „ P¹ ...	115'	4	0 14 11	1 13 10	2 12 9	3 11 8	...	...	...	...	...	...
„ „ R¹ ...	176'	9	0 12 1	1 8 2	2 4 3	3 0 4	3 12 5	4 8 6	...	...	...	...
„ „ S¹ ...	152'	9	0 12 7	1 9 2	2 5 9	3 2 4	3 14 11	5 8 1	...	...	...	...
„ „ T¹ ...	149'	6	0 9 4	1 2 8	1 12 0	2 5 4	2 14 8	...	...	...	...	...
„ „ U¹ ...	336'	51	1 1 3	2 2 6	3 3 9	4 5 0	5 6 3	6 7 6	7 8 9	8 10 0	9 11 3	10 12 6
„ „ W¹ ...	253'	20	0 12 5	1 8 10	2 5 3	3 1 8	3 14 1	4 8 6	5 4 11	6 1 4	6 13 9	...

W. NESS,
Mining Engineer.

Return shewing rate of progress and cost of bore holes in the Wún District of the Wardha Valley Coal-field.

NAME OF BORE HOLE.	Total depth of bore hole.		Total number of days taken.	Total number of days boring 1st 100 feet.	Total number of days boring 2nd 100 feet.	Total number of days boring 3rd 100 feet.	Total number of days boring 4th 100 feet.	Average depth bored per day.		Average depth bored per day for 1st 100 feet.		Average depth bored per day for 2nd 100 feet.		Average depth bored per day for 3rd 100 feet.		Average depth bored per day for 4th 100 feet.		Total cost of each bore hole.			Average cost per foot for 1st 100 feet.			Average cost per foot for 2nd 100 feet.			Average cost per foot for 3rd 100 feet.			Average cost per foot for 4th 100 feet.			Average cost per foot for total depth.		
	Ft.	In.	Days.	Days.	Days.	Days.	Days.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Rs.	As.	P.	Rs.	As.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
Papur, No. 1	110	...	12	10½	1⅓	...	...	9	2	9	6	6	6	...	...	...	...	99	12	0	0	14	3·4	1	10	0·7	...	...	...	...	...	...	0	14	6·1
Pisgaon, No. 7	129	...	4	2⅓	1⅓	...	...	32	3	40	0	19	4	...	...	...	...	57	0	0	0	5	8·4	1	7	7	...	...	...	...	...	...	0	7	0·8
Pisgaon, No. 9	333	...	43	5	12	20	6	7	8·9	20	0	8	4	5	0	5	6	419	4	0	0	6	9·6	1	2	8·6	1	15	2·4	2	5	6·1	1	4	1·7
Pisgaon, No. 11	155	...	13	5	8	...	...	11	11	20	0	6	8	...	...	...	...	185	4	0	0	11	4·8	2	15	1·4	...	...	...	...	...	...	1	3	1·4
Warura, No. 1	231	...	28	6	14	8	...	8	3	16	8	7	1·7	3	10½	...	...	399	0	0	0	13	8·1	1	15	11	2	8	5·4	0	...	...	1	11	7·8
Warura, No. 2	162	...	11	6	5	...	...	14	8·7	16	8	12	4·8	...	...	...	...	156	12	0	0	13	8·1	2	5	4·4	...	...	...	0	0	...	0	15	5·7
Warura, No. 3A	158	...	16	10	6	...	...	9	11·1	10	0	9	9·8	...	...	...	...	228	0	0	0	4	2·6	2	15	1·9	...	...	...	0	0	...	1	5	2
Wún	310	10	42	5	8	26	3	7	4·8	20	0	12	9·6	3	10·1	3	7·3	470	4	0	0	9	1·4	0	13	7·2	2	15	10·4	2	2	8·4	1	8	0·8

R. BATEMAN SMYTH,
Offg. Supdt. Pisgaon Coal Mines.

15th May 1875.

In the statement of expenses made by Mr. Ness there is a regular augmentation in the price of labor for every additional ten yards, equal to the cost of the first ten. Mr. Smyth has entered more into details, and thus rendered his returns more useful and more interesting. There is no regular rate of increase in the charges.

The deepest hole (that of Pisgaon No. 9) 333 feet in depth, occupied only 43 days, and was put down at an average speed of 20 feet a day for the *first* 100 feet, 8 feet 4 inches a day for the *second* 100 feet, 5 feet a day for the *third* 100 feet, and 5 feet 6 inches for the portion of the *fourth* 100 feet. This is a rate of progress which, I think, must be admitted to be satisfactory. The rocks are principally sandstone, but there are some bands of clay, and these reduced the averages of speed considerably. The following is the section of the strata passed through:—

Pisgaon—No. 9. WÚN DISTRICT.

	Ft.	In.
1. Surface soil	5	0
2. Sandstone, yellow	12	0
3. Ditto, red	1	0
4. Ditto, yellow	15	0
5. Ditto, red	6	0
6. Ditto, reddish-yellow	10	0
7. Ditto, yellow	9	0
8. Ditto, red	17	0
9. Ditto, yellow	2	0
10. Ditto, reddish-yellow	3	0
11. Ditto, red	14	0
12. Ditto, yellow	1	0
13. Ditto, red	6	0
14. Ditto, yellow	2	0
15. Ditto, red	2	0
16. *Clay*, red	7	0
17. Sandstone, red	10	0
18. Ditto, yellow	9	0
19. Ditto, red	4	0
20. Ditto, yellow	4	0
21. Ditto, red	7	0
22. Ditto, yellow	7	0
23. Ditto, red	3	0
24. Ditto, yellow	34	0
25. Black carbonaceous earth	2	0
26. *Clay*	9	0
27. Sandstone, white	22	0
28. *Clay*, blue	4	0
29. Sandstone, white	33	0
30. Clay, blue	8	0
31. Sandstone, white	40	0
32. Clay	2	0
33. Clay, grey micaceous	3	0
34. Sandstone, white	20	0
TOTAL	333	0

NOTE ON THE GEOLOGY OF INDIA, *by* DR. W. WAAGEN, *formerly Palæontologist to the Geological Survey of India.*

(Translated from the "*Zeitschrift der Deutschen Geologischen Gesellschaft*," Vol. XXVIII, p. 644, 1876.)*

The work which I do myself the honor of presenting to you is only in its later parts of very recent date. The first fasciculus has been already more than two years published. I have, however, noticed the general results only in a concluding chapter; and it is those especially which can be of general interest.

First, to rectify some errors which occurred owing to my illness and the consequent impossibility of my personal supervision of the preparation of the plates, I must mention that the last plate is altogether a failure, only the figure of *Crioceras australe* being recognisable. Instead of *Amm. Deshayesi* there is figured the fragment of a Plannlata from the Macrocephalus-beds, under the title of "*Amm. Martini*;" and the true *Martini* is exhibited as "*Amm. Deshayesi*," but delineated so that the figure is quite useless for the recognition of the species.† Other errors, such as the misnumbering of one plate, are easily detected and are therefore of less consequence.

The most striking result of the study of the Cutch ammonites is that the species identical with those of Europe are here also distributed strictly in the same horizons as have been distinguished there. This discovery is, indeed, due less to me than to the late Dr. Stoliczka, who, although fully convinced before his visit to Cutch that it is impossible to identify the European horizons in India, could not escape making the stratigraphical groups I have adopted in this work, and which do conform to the arrangement of the European zones.

It is also a very noteworthy fact, that among the ammonites the Macrocephala have a very different distribution in India from what they have in Europe; for they still occur numerously in a zone corresponding to that of the *Pelt. transversarium* in Europe. The species are, no doubt, clearly distinct from those of Europe; still they belong to the Macrocephala.

I have only noticed these two facts cursorily. I wish to speak more fully of the distribution of the jurassic strata in India, for upon this particularly depends to a certain extent the apprehension of Indian geology. It has been long known that the peculiar relation of Indian strata is that, while nearly the entire mesozoic formations are represented in the peninsula itself by thick sandstone deposits (Rajmahal, Mahadeva, Jubbulpur, &c.) with plant-impressions and some vertebrate remains, on passing to the North-West Himalaya one finds numerous marine fossils, which give certainty in the discrimination of the formations. On this account, according to Blanford's example, a Himalayan and a Peninsular type have been distinguished, and the areas compared with the alpine and extra-alpine formations of Europe. Only the Punjab does not seem to fit in this place, for there we find exclusively marine fossils, although one can scarcely place the neighbourhood of the Indus delta with the Himalaya. As a fact, however, this is the key to the solution of the whole problem.

* This communication was made by Dr. Waagen on the occasion of presenting his work in the Palæontologia Indica to the German Geological Society. Besides its direct bearing upon the geology of India, the paper is in many ways so illustrative, that it is worth while to reproduce it here.—H. B. M.

† A new plate is in hand, which will be sent to replace the defective one.—H. B. M.

In passing eastwards from the marine strata in Cutch and Rajputana, one comes at once upon the crystalline range of the Aravalis, to the south-east of which we only find the barren sandstones of the peninsular area. The Aravali range was never crossed by the sea (till the cretaceous period), and we have in the formations of the Peninsular type deposits from inland waters, which are manifold in their arrangement and therefore difficult to affiliate individually. They must, however, altogether belong to the Trias-jura period.

If we follow the crystalline rocks of the Aravali northwards, they become lost under the alluvial, nummulitic, or younger tertiary formations; but we behold to our astonishment that in the Himalaya, in the neighbourhood of Simla, the first crystalline ridge performs the same function as the Aravalis in the south,—namely, the separation of the fossiliferous marine clays and limestones from the thinly fossiliferous sandstone deposits. Poor Medlicott was wrongfully so much decried for his description of the neighbourhood of Simla. It is only natural that his Krol and Blini groups, if indeed they are not nummulitic, should not be found north of the first crystalline ridge; one must rather look for their equivalents in the south in Central India.*

The first crystalline range does not, however, remain the dividing line throughout the entire length of the Himalaya; for to the south-east in Sikkim the marine strata are already entirely cut out, and only one locality is known containing fossil plants. The sedimentary rocks are, moreover, here in great part converted into crystalline schists. The dividing line must cross to the north somewhere in Nepal and so extend into Tibet.

Thus is India traversed by an ancient coast-line which began with the Aravalis, probably reached the Himalaya west of Simla, then followed for a stretch the first crystalline axis and turned northwards in Nepal cutting obliquely across the whole Himalayan range. It seems, therefore, that the peninsula belonged to a great continent which probably included China, the Himalayan peninsula, the Archipelago and Australia, perhaps even a part of Oceania. The configuration was constant, with slight alterations, during the Trias-jura; great depressions set in with the chalk, which determined a great encroachment of these deposits, but already in mesozoic times India formed a peninsula as today, as is shown by the presence of triassic rocks in Burma, and marine jurassics north of Madras, which indicate a bay like that of Bengal.

The sea surrounding this peninsula was no doubt connected on the north with the European seas,—for how else could these seas have so many species in common? On the south it stretched away to east and west, as testified by the jurassic beds of South Africa and Australia, allied to those of India.

Especially remarkable is it that the Himalayan jura, although so near, is almost less like the Cutch jura than is the jura of West Australia; it is more like the Russian jura. Thus it would follow that the jura of Europe, Cutch and Australia, although in different provinces, forms in a manner a whole that one may at least designate as a homozoic girdle, while the jura of Spiti must indicate a similar girdle, to which that of Russia and Siberia must be affiliated.

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* We were not aware of the criticisms referred to; but it would have been more to the point if Dr. Waagen had informed his hearers that several years later Dr. Stoliczka, the only competent observer who has visited both grounds, did identify conjecturally the Krol and Blini beds with the Triassic and Silurian beds of Tibet (see Memoirs Geol. Surv. Ind., Vol. V, p. 141). The conjecture still stands for what it may be worth. Dr. Waagen never set foot on Himalayan ground proper, i. e., east of the Jhelum.—H. B. M.

Finally, I may mention that a part of the original specimens for the work before us seem to have been mislaid or lost during the transfer to the new museum building, as I am informed from Calcutta that several of the originals are not to be found.*

NOTE.—This key to the geology of India is one of the oldest on our bunch. But somehow the author of the paper must have taken a wrong impression of it, for his copy sticks in the lock. At least it seems curious how the recognition of the trans-Arvali rocks as belonging to the Himalayan region, should lead directly to the conclusion that the jurassics of Western India are more related to those of the antipodes than to those of the Himalayas. There must have been some difficult navigation round that ancient mesozoic coast-line, the course of which we here find traced with such accuracy, even into regions whose geology is absolutely unknown.

To any one who has attempted to understand the meaning of the correlation of widely separated deposits, even from copious fossil evidence, the assurance with which such conclusions as these are put forward will suggest want of confidence. If to the intrinsic uncertainties it be added that the data in this case are not abundant and have been only partially worked out, that collateral stratigraphical conditions are ignored, assumed, or misstated, the impression of doubt will become one of despair. The paper is one of a kind that is now only too common. The production of them is no doubt encouraged by the principle of mutual laudation which is the evil spirit of scientific societies. A curious collection, illustrative of this class of literature, might be made under the title, Oracular Palæontology. It must be a survival (largely Teutonic) of the barbaric instinct to deal in mysteries. The saying Arago applied to the geologists of his day may now be more fittingly addressed to their colleagues—"Je ne conçois pas comment deux pures paléontologues peuvent se regarder sans rire."

H. B. M.

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Fossils from six localities of the Gondwána and intertrappean rocks near Warora ... ... Walter Ness, Esq.

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INDIA OFFICE.

* Every one of the originals is now in its place in the new museum.—H. B. M.

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Annales des Sciences Naturelles, Series I, Vols. I (1824)—XXX (1833); Series II, Vols. I (1834)—XX (1843); Series III, Vols. I (1844)—XX (1853); Series IV, Vols. I (1854)—XX (1863); and Series V, Vols. I (1864)—XX (1874), with 9 Vols. of Plates and Atlas, 8vo., Paris.

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Geographical Magazine, Vols. III, Nos. 11 and 12; and IV, No. 2 (1876-77), royal 8vo., London.

Geological Magazine, New Series, Decade II, Vol. III, No. 12, and Vol. IV, Nos. 1 and 2 (1876-77), 8vo., London.

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April 12th, 1877.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1877. [February.

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1876.

Gondwana formation.—The past year has certainly been one of special advance in our knowledge of Indian formations; we have at last successfully grappled with our great plant-bearing series of rocks, now known as the Gondwana system—the only extensive fossiliferous formation of peninsular India. This advance is, of course, due to palæontological aid. The splendid work on the cretaceous fauna of Southern India, produced by Dr. Stoliczka in the Palæontologia Indica, after several years' labour, will no doubt, for a long time to come, be a standard of reference in the examination of rocks of that age, besides its independent merits as a study of a great branch of natural history. The same may be said of the work on the Jurassic Cephalopoda of Kach by Dr. Waagen, noticed in the last annual report. Yet it is not too much to say that the results of a few months' study by Dr. Feistmantel have been of more immediate service to the Survey.

The explanation of this is simple. Both the treatises referred to deal with rocks that only occur in patches on the outskirts of the peninsula, whereas the Gondwana deposits occupy large areas; and, on account of their economic importance, they have been from the beginning the chief object of our investigations. It would seem as if there were here a case of misdirected labour; but it must be recollected that, on the whole, marine creatures form an immense proportion of fossil remains; and, as a consequence, comparatively few palæontologists are capable of dealing with a fossil flora. I am happy to say we are now well provided in this way.

As an illustration of these results, I may mention the case of a large spread of rocks marked down by Mr. Hughes in the Pranhita valley. Two localities of this area have for many years been famous as having yielded remarkable vertebrate fossils, from which, and from the general [illegible] the deposits, it had been considered that these beds were on the horizon of the Panchets, in the lower Gondwana series of Bengal. This year a few poor plant-fossils were found with the bone beds of Kota and Maleri. From these, and in their order of superposition, Dr. Feistmantel at once detected representatives of two groups of upper Gondwana deposits, the Jabalpur and Rajmahal, established by him from the study of the floras of the typical areas.

This case affords also an example of independant verification, which is always such a welcome encouragement, as a confirmation of the soundness of our methods. Where the Gondwana rocks tail down towards the sea, on the border of the Godavari delta, they

become associated with marine beds. Mr. King has been for some time working in this region, and has established three well-marked groups in upper Gondwana rocks,—a bottom one, with a well characterized Rajmahal flora, and two upper ones, with distinctive marine fossils. From a cursory inspection of these latter specimens, Dr. Stoliczka had recognized the upper group as corresponding with his Umia group, at the top of the jurassic series of Kach, with the flora of which group Dr. Feistmantel has identified that of the Jabalpur group of the Narbada and Sone regions. During the past season, Mr. King was directed to make a traverse up the Godavari, to bring his work into connection with Mr. Hughes' ground on the Wardha and Pranhita. He has satisfactorily recognised in the Kota-Maleri area representatives of his three upper Gondwana zones of the Lower Godavari.

While thus the internal economy of the Gondwana system is being regulated in a most satisfactory manner, I fear that its foreign relations are being somewhat mismanaged. They are now quite a burning question amongst us. Palæontologists come from their cabinets in Europe with the fixed idea that the "laws" they have seen to work so neatly as between Bohemia and Bavaria, or from Durham to Dorsetshire, will apply equally well between India and Australia, or Europe; and the eager aim of their labours seems to be to tally off our Indian rock-groups as the representatives, or equivalents, of certain fossiliferous series of Europe or elsewhere. From the beginning, this palæontological fallacy has been a chief obstruction to our knowledge. When first the Gondwana fossils were taken up, pure geology being in the ascendant, the fact that certain plant-forms of the lower Gondwana rocks were somehow associated with beds having a carboniferous marine fauna in Australia, was made the basis of a special-pleading to show that the Damudas, their flora, and their coal were palæozoic. The materials have now come into the hands of a pure palæontologist. He has shown, I believe conclusively, that the Gondwana flora is wholly mesozoic, nailing its several phases to certain representative zones in Europe. But it so happens that on the confines of India, east and west, the upper Gondwana groups are associated with beds having a marine fauna, according to which these said groups have already been attached by palæontological experts to other standard groups in Europe. It is true that the study of this fauna was only partial; but the experts were very accomplished in their line, and their judgment was quite unprejudiced, so that it must carry great weight. Here then, again, is an opening for the procrustean method of research; and there are symptoms that it is to be duly applied; this time, to make the fauna conform to the flora. The expression 'palæontological contradiction,' which has been applied to this fact of association, exhibits the predicament in a very naïve manner. The contradiction is certainly there, but only as a rebuke for those who can look upon it in that light. No theologian could be more impious in reducing the mysteries of existence to the compass of his narrow thoughts, than are often scientific specialists in imposing crude conceptions upon the proceedings of nature. Yet these ought to know better—that truth is discovered, not invented.

The treatment the facts of our Gondwana system have thus received in the name of homotaxis is quite opposed to scientific principles. It is fiction to assume that palæozoic and mesozoic faunas have not co-existed upon the earth. The very word *homotaxis* was introduced to meet facts of this order. Yet, when some approach to it is met with in the rocks, a lively dispute is set up as to which fauna is out of place! The dispute becomes doubly awkward when waged over a terrestrial flora *versus* a marine fauna. A compromise that the marine fauna should take precedence would be a miserable confession of weakness, and quite out of place in a rational investigation. It would only tend to crystallize that false notion of misplacement; to frustrate, in fact, that fruitful conception of a purely biological homotaxis which should be as a pole-star to the palæontologist. The vicious practices of giving different specific names to fossils for no other reason than that they occur on different stratigraphical horizons, even at distant localities, and of trimming

species to suit a fancied age, are the offspring of these false assumptions. Such a practice must utterly confound the attempt to work-out the natural history of organic evolution.

The facts of our Gondwana rocks are certainly puzzling to systematists: on the west, in Kach (Cutch) we have the flora of the top Gondwana group, which has a Bathonian facies, associated with marine fossils of Tithonian affinities; while on the south-east, in Trichinopoli, beds with a flora (so far as known) like that of the Rajmahal group, which is taken to be liassic, have been described by Mr. H. F. Blanford* as overlaid, in very close relation, by the Ootatoor group, the fauna of which' has been declared, upon very full evidence, to have a Cenomanien facies.

These questions of homotaxis concern the whole body of naturalists as much as they do us; and I hope some guiding spirits amongst them will keep a watch on our proceedings. Happily these foreign relations do not interfere with the local regulation of our rock-systems. The terrestrial fauna and flora of the Gondwanas is developing into a compact unity of its own, and its relations to contiguous marine fossil faunas is normal, so far as this word can be legitimately used.

Omitting the original account of the Narbada or Satpura field, in which the succession of the rocks was altogether misunderstood, the Survey has hitherto been engaged almost entirely upon outliers of the Gondwana system, where the series is more or less broken. This order has been imposed upon us by geographical and economical conditions. The great central areas of South Riwah and the Satpuras have still to be worked in detail. The latter seems to present a very full series in unbroken succession. It is here that we may expect ultimately to establish a better knowledge of this important formation.

The work of Messrs. King and Hughes on these rocks has been noticed above. Mr. Foote was also engaged on the same formations, in examining the chain of outliers of upper Gondwana deposits along the coast of the Carnatic. He sent in a fine series of fossils from these beds at Vamavaram.

It had been arranged that Mr. Ball should make an exploration of the large area of unknown country between the Mahanadi and the Godavari; but he was detained to investigate the re-discovery of the Talchir coal-field by the Civil Officers of Orissa. In connection with this duty, he was able to complete the mapping of the Raigarh and Hingir coal-basin, which is on the south-east extension of the great Gondwana area of South Riwah and Sirguja. A narrow strip of Talchir beds stretches from that basin to within two miles of the Talchir field. He also examined the sedimentary basin west of Cuttack, on the margin of the Mahanadi delta, and procured some plant-fossils from the Atgarh sandstone, which Dr. Feistmantel recognises as of the Rajmahal flora.

Tertiary formations.—An important gap in our knowledge of the Sub-Himalayan tertiaries has been filled up by the past season's field-work. MM. Medlicott, Theobald and Lydekker made an outline-survey of the broad band of tertiary deposits flanking the Pir Panjal, in the Jamu territory, thus connecting previous work in the Cis-Ravi and Trans-Jhelam regions. The discrepancy that existed in the sections of these two regions has been, in a manner, interpreted—by the greater, and thereby earlier, elevation in the direction of the Central Himalaya, whereby the apparently unbroken succession of deposits, from the nummulitic to the upper Siwaliks, as exhibited on the Jhelam, becomes gradually separated into bands that are at least locally unconformable. The extreme effect of this is exhibited in the oldest beds: the inner belt of nummulitic and associated deposits

Memoirs, Geological Survey, Vol. IV, page 47.

is in great force all through the Jamu hills; at the Ravi it becomes contracted; at the Sutlej it is upraised on a base of the older formations of the higher mountains; before reaching the Jamna, it has been completely and permanently removed by denudation. East of the Jamna there only remain the outer zones, composed of Siwalik rocks.

The complete change of strike that occurs so abruptly along the valley of the Jhelam has been shown to be quite a continuous feature, not connected with any marked difference in the age of the contrasting systems of disturbance.

Our chief disappointment in this ground was not being able to determine satisfactorily the age of the great inliers of old limestone that in several places obtrudes through the inner zone of tertiary rocks in Jamu. From some obscure indications of fossils, they have been coloured on the sketch-map as carboniferous; but this is quite an open question. The triassic age of the fringe of limestone along the base of the Pir Panjal is also more or less conjectural.

This trip afforded an opportunity of testing the speculations published in our Records for 1874 by Mr. Theobald, on ancient glaciers in the Kangra district. The conclusion was come to that the so-called moraines are only the remains of a diluvial deposit that had once deeply covered the valley.* At the same time it is difficult to account for the characters of this deposit without the supposition of active glacial conditions on the Dhaoladhar range. The coincidence is not to be lost sight of that these high-level gravels along the Himalayan border, locally with glacial characters, are, according to physical methods of computation, of an early pleistocene age, more or less corresponding to that of the glacial period of Europe.

In connection with the tertiary rocks we can also claim for the past year a special advance in our knowledge, and again through palæontological aid. Since the labours of Cautley and Falconer, the fossil vertebrates have been the subject of most wide-spread interest in Indian geology. We have at last been able to make a beginning in carrying on that line of research. I trust that Mr. Lydekker's papers in our publications for 1876 will fully support this promise. A general result, so far, seems to be that the Siwalik fauna is of pliocene rather than of miocene affinities; but we have still made very little way in marking stages in this great tertiary fauna. This difficulty is, of course, one of field-geology, and it is very great. There is an enormous succession of conformable deposits, with much uniformity of character throughout, and fossils are very rare except in one broad zone having an upper middle position in the series. The whole formation, moreover, has undergone extreme disturbance.

The conjectured identification of the topmost Siwalik beds with the ossiferous deposits of the Narbada valley is one of great interest, on account of the discovery in these of a well-formed stone implement, as described in the Records for 1873.

In the far east, in upper Assam, Mr. Mallet completed his survey of the coal-fields of the Naga hills. For the extent and quality of the coal this is certainly the most important of our Indian coal-fields, and yet it is entirely of tertiary age, possibly even middle tertiary. On account of the total change in the character of the associated rocks, the relation of these measures to the nummulitic coal of the Khasia hills could not be established without a continuous survey of the intervening ground; but the intimate connection of the Assam measures with overlying deposits of Siwalik type, suggests that they may be on a higher horizon.

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* Records, Vol. IX, page 56, 1876.

On the south-west extension of the Sub-Himalayan series Mr. Blanford, assisted by Mr. Fedden, accomplished a good season's work on the tertiary deposits in Sind. A preliminary sketch of these formations, from the previous season's field-work, was published by Mr. Blanford in the Records for 1876 (p. 8). The most important addition made to the geology of Sind since the date of that report consists in the discovery of cretaceous rocks (a Hippurite limestone) at the base of a group of beds underlying the Ranikot or infra-nummulitic group. Several very important facts concerning this group have also been ascertained; its upper limits and the division between it and the overlying Kirthar group have been better defined, and very large additions have been made to the fossils obtained from it. Mr. Fedden during the recess season in Calcutta has made a very useful preliminary classification of these collections in the Museum. It has further been definitely ascertained that the basalt of Ranikot is interstratified with the sandstones and shales of the Ranikot group; and a bed of basaltic rock, apparently the same, has been traced at intervals to Jakhmari, a distance of over 20 miles. This basalt is on the horizon assigned for the Deccan trap.

Older rocks.—Early in 1876 Mr. Blanford made an important trip across the desert east of the Indus, through Umarkot and Balmir to Jodhpur, and back through Jesalmir to Rohri. We have thus gained most interesting information regarding a great area of western Rajpootana that has hitherto been almost unknown. The journey did not quite extend to the gneissic and slate rocks forming the centre of the Arvali region. The oldest formation observed on the inner zone consisted of peculiar porphyroid rocks; a prevailing type being a dark compact silicious felsite with disseminated felspar crystals and quartz, associated with syenitic and granitoid varieties. They are locally much disturbed. Mr. Blanford supposes these Maláni beds to be altered volcanic rocks.* He does not liken them to any he has seen elsewhere in India; but it may be worth recalling that peculiar felsitic beds have been described in the Kadapah and Gwalior formations, and even in the Lower Vindhyans of the Sone valley.

Upon these rocks, in the neighbourhood of Jodhpur, there rest quite unaltered and very little disturbed a considerable thickness of rusty sandstones, at the base of which Mr. Blanford doubtfully places a very peculiar contiguous deposit of fine shales with large boulders, which suggest the action of ice, the supporting rock having, moreover, exhibited in one place a smoothed and scored surface. A Vindhyan horizon is suggested for these deposits, and the specimens are certainly most of that type; otherwise one might risk the conjecture that they may be lower Gondwanas, and that the boulder-bed represents that of the Talchirs.

The relation of the Jodhpur sandstones to the next formation on the west has not been defined, the two not having been observed in proximity; but the unconformity must be total, as the succeeding deposits, within a small distance, also rest upon the Maláni felsitic series. They consist of brown and white sandstones in which silicified wood and other plant remains are frequent. The fossils of these Balmir beds are not identifiable, but the rocks have a strong Gondwana aspect, and may safely be reckoned as such, being closely related to the overlying marine jurassic rocks of Jesalmir, consisting of alternating sandstones and limestones.

The marine jurassics of Jesalmir are transgressively overlaid on the west by a nummulitic limestone, identical with that of the Kirthar group, as seen at Rohri on the Indus. All the infra-nummulitic and cretaceous beds of the trans-Indus section are thus totally over-

* I notice a contemporaneous description of very similar rocks of palæozoic age in Australia as altered volcanic products. See Mr. Brough Smith's Report of Progress of the Geological Survey of Victoria, No. III, p. 199, 1876.

lapped. For a full account of these important observations I may refer to Mr. Blanford's paper in the current number of the Records.

The observations just noted have supplied a knowledge of the western margin of a well-defined but little explored geological region—that of which the Arvali hills (or mountains) form the best-known geographical feature, stretching to the south-south-west into Guzerat, and passing on the north north-east under the Indo-Gangetic plains, about their water-shed, and touching the Jamna at Delhi. The eastern limits of the region are very well marked by the scarp at the Vindhyans, stretching from near Agra to Chittorgarh and Neemuch, and thence by the scarp of the Malwa plateau formed of the Deccan trap. The Arvali region is believed to be formed entirely of gneissic and transition rocks, the remains of an exceedingly ancient mountain system, or area of special disturbance; even the Vindhyan formation exhibits little disturbance within its confines. For some seasons past Mr. Hacket has been engaged upon these rocks in the north. Last year he carried his lines as far as Jaipur. The isolated condition of the outcrops, in detached ridges and hills separated by wide plains of sand or of alluviun, makes it very difficult to discover the normal order of succession of the several groups of rocks, all being without a trace of fossil remains. Our difficulty here at present is the occurrence, within a moderately large area, of several strong rock-groups, having much mutual resemblance, and each independently in natural contact with a fundamental gneiss.

Mr. Willson was also engaged upon the older rocks, having completed the mapping of the Bijawar formation in Bundelkund, with a large adjoining area of overlying lower and upper Vindhyans, and of the underlying gneiss.

Mr. Wynne did not return from furlough till the end of the field season. He has since done important work in the Museum in arranging the Kach and Salt Range collections.

For the first time since the institution of the Survey the annual report has to record the retirement upon pension of any of the staff. Dr. Oldham resigned the post of Superintendent in April, after a tenure of 25 years. The work done up to date will form a permanent record of the value of his services. Mr. Tween retired in September, after a service of 15 years, for the greater part of which time he had zealously performed the duties of Chemist to the Survey. In both cases, failing health made the step unavoidable. The loss we have thus sustained is the more felt, since it is determined that, for the present at least, the number of our staff cannot be restored to its full strength.

Publications.—Of the MEMOIRS of the GEOLOGICAL SURVEY of INDIA, Volume XII was issued during the past year. Part 1 is the result of several seasons' work by Mr. R. Bruce Foote, and includes a very large area in the South Mahratta Country, where several basins of our azoic formations occur between the great spread of the Deccan trap on the north and the gneiss forming the whole middle area of the peninsula to the south. The small skeleton-map attached to the Memoir does very poor justice to the accuracy and detail of Mr. Foote's work, the whole of which is ready for publication on the Indian Atlas sheets, as soon as a plan can be matured for the regular issue of our work in that form. Part 2 is Mr. Mallet's report on the coal-fields of Upper Assam. It will be a very useful guide in the practical exploration of that field.

Volume XIII was fully passed for press before the close of the year. Part 1, containing Mr. Hughes' memoir and maps of the Wardha valley coal-fields, will be issued before the

date of this report. Part 2 is Mr. Ball's memoir on the Rajmahal Hills, with numerous maps and illustrations, the preparation of which has caused some delay.

I am happy to be able to announce that good progress has been made in the preparation of a Manual of the Geology of India. The map was sent in for colour-printing in July last, but it is a very heavy piece of work. Several of the plates of fossils are already printed, and I hope the work may be ready for issue about the middle of the current year.

The RECORDS for 1876 contain many papers giving abstracts of current work, or discussing important questions relating to it.

Of the PALÆONTOLOGIA INDICA the Jurassic Flora of Kach, with 12 plates, was issued in December. A similar treatise on the Flora of the Rajmahal Hills is nearly ready for issue. The publication of these figures and descriptions of the plant-remains of the Gondwana system will be of immense service in working out those formations, large areas of which still remain to be examined.

A fasciculus by Mr. Lydekker, with seven plates, on some tertiary vertebrate remains will be issued before the date of this report. Of all the work we have in hand none will be received with so much interest as information regarding tertiary and post-tertiary mammalia.

I have the pleasure to record that a first class medal was awarded for the exhibits of the Geological Survey of India at the Congrès International des Sciences Géographiques, held at Paris in 1875.

Library.—The Library of the Geological Survey has received an addition of 992 volumes or parts of volumes during the year 1876.

Of this number 536 were purchased and 456 were received from Societies and other Institutions in exchange for the publications of the Survey, or as donations.

Quarterly lists of these additions are published in the Records, and a nominal list of Societies and Institutions from which presentations or exchanges have been received is appended.

Museum.—Much has been done during the past year in getting the new museum into order. The mineralogical gallery is now fairly provided with cases, and the systematic arrangement of the collections has made good progress. Mr. Mallet's catalogue of the minerals will, I hope, be ready for publication this year. In the palæontological galleries no new case-room has been as yet provided, so that large parts of the collections are unavailable for show or for study. The cases we have are being used for the Indian specimens. The several series of the general collections have for the present to be packed away. The specimens of the Asiatic Society's collections have been amalgamated with those of the Geological Survey in the Indian Museum.

CALCUTTA,
February 1877.

H. B. MEDLICOTT,
Supdt. of Geological Survey of India.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1876.

AMSTERDAM.—Royal Society of Batavia.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
" Royal Prussian Academy of Sciences.
BOMBAY.—Bombay Branch of Royal Asiatic Society.
BOSTON.—Museum of Comparative Zoology.
" Boston Society of Natural History.
" American Academy of Arts and Sciences.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Naturalists' Society of Bristol.
BRUSSELS.—Royal Academy of Sciences.
BUFFALO.—Buffalo Society of Natural Sciences.
BUDAPEST.—Royal Geological Institute of Hungary.
CALCUTTA.—Asiatic Society of Bengal.
" Agricultural and Horticultural Society.
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—The Isis Society.
" The Leopoldino Carolina Academy of Naturalists.
" The Royal Museum.
DUBLIN.—The Royal Dublin Society.
" Royal Geological Society of Ireland.
EDINBURGH.—Royal Scottish Society of Arts.
" Royal Society of Edinburgh.
GENEVA.—Physical and Natural History Society of Geneva.
GLASGOW.—Philosophical Society of Glasgow.
" Glasgow University.
GÖTTINGEN.—Royal Society of Science.
JEFFERSON CITY.—Geological Survey of Missouri.
KÖNIGSBURG.—Royal Society.
LAUSANNE.—Vaudois Society of Natural Science.
LIVERPOOL.—Literary and Philosophical Society of Liverpool.
" Geological Society of Liverpool.
LONDON.—Royal Geographical Society.
" Royal Society.
" Geological Society of London.
" Royal Asiatic Society of Great Britain and Ireland.
" British Museum.
" Linnæan Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Geological Survey of Victoria.
" Mining Department, Victoria.
" Royal Society of Victoria.
MONTREAL.—Geological Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Science.
NEW HAVEN.—The Editors of the American Journal of Science.

NEW ZEALAND.—Geological Survey of New Zealand.
„ New Zealand Institute.
PALERMO.—The Royal Institute.
PARIS.—Mining Department.
„ Geological Society of France.
„ Anthropological Society.
PHILADELPHIA.—American Philosopical Society.
„ Academy of Natural Sciences.
„ Franklin Institute.
PLYMOUTH.—Devonshire Association.
„ Geological Society of Cornwall.
PISA.—Natural History Society of Tuscany.
ROME.—Geological Commission of Italy.
ROORKEE.—Thomason College of Civil Engineering.
SALEM., MASS., U. S. A.—American Association for the advancement of Science.
„ Essex Institute.
„ Peabody Academy.
STOCKHOLM.—Bureau Géologique de la Suède.
„ Royal Academy.
SYDNEY.—Philosophical Society of New South Wales.
„ Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Science.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Smithsonian Institute.
„ United States Geological Survey.
„ Dept. of Agriculture, U. S., A.
YOKOHAMA.—German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Swiss Natural History Society.

Governments of India, Madras, Bombay, North-Western Provinces and the Punjab ; Chief Commissioners of British Burmah, Central Provinces and Mysore; Surveyor-General of India, Superintendent of the Great Trigonometrical Survey of India, and the Meteorological Reporter to Government.

GEOLOGICAL NOTES ON THE GREAT INDIAN DESERT BETWEEN SIND AND RÁJPÚTÁNA.

BY W. T. BLANFORD, A.R.S.M., F.R.S., &c., *Geological Survey of India.*

I.—INTRODUCTION.

The following notes were made during two traverses of the great desert region east of the Indus,—the first from Sehwan on the Indus through Umarkot, in the Thar and Parkar division of Sind, to Jodhpúr, *viâ* Bálmír, the second further north and in the reverse direction, from Jodhpúr to Rohrí on the Indus, *viâ* Jesalmír. The length of the first traverse was above 350 miles; of the second about 300.

The only previous geological notices of any part of this tract with which I am acquainted consist of a few remarks by Dr. Carter in his "Summary of the Geology of India between the Ganges, the Indus, and Cape Comorin,"* principally relating to the occurrence of granitic rocks near Bálmír, and of some further details procured by the same author from Dr. Impey† concerning the rocks seen on a journey from Rohrí to Jodhpúr *viâ* Jesalmír, Dr. Impey's most important observations being the occurrence of ammonites at Kuchrí and of fossil wood at Láthí. The ammonites were referred by Dr. Carter to *A. opis*, Sow., a Jurassic species found in Cutch (Kachh).

The physical geography of the region has been frequently described; the latest and best description with which I am acquainted being by Sir H. B. E. Frere‡. On this subject I have already published some notes recently§.

II.—DESCRIPTION OF ROUTE FROM UMARKOT TO JODHPÚR.

Sandhills and lakes east of the Eastern Nárra.—From the Indus near Sehwan to the Eastern Nárra, the route lay over the alluvium of the Indus Valley. The Eastern Nárra is an ancient river channel by which the Indus probably, at one time, poured its waters into the western portion of the Ran of Cutch. Immediately to the east of the Nárra a change takes place, nearly the whole surface of the country being composed of sandhills running in parallel lines with a general north-east—south-west direction. Between the sandhills are long stretches of water, many of them extending for as much as 15 or 20 miles, of considerable depth, supplied from the Nárra. Farther to the eastward, amongst the sandhills, are isolated pools of water, all of them salt; the saltest, which are a saturated solution of brine, being farthest east and containing, besides common salt, sulphate of lime in sufficient quantity for crystals of gypsum to be formed. These salt-ponds are at a lower level than the long lakes near the Nárra, and apparently derive their water from the latter by percolation, for water always runs in at their western extremities, and the salt must be derived from the soil. It is evident that the original surface of the country can have been no higher than the bottom of the lakes, which is at a depth of many feet below the channel of the Nárra, itself beneath the general level of the Indus alluvium. It is also manifest that the soil beneath the sandhills is strongly impregnated with salt. Both these circumstances are in favour of this tract of country having been an arm of the sea in recent times, and this probability is confirmed by the existence in some of the brackish water lakes of a mollusk, *Potamides* (*Pirenella*) *Layardi*, H. Ad., which inhabits salt-lagoons on the coast, and must in all probability have found its way to these now isolated pools of water when they were in communication with the sea.

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* Jour., Bombay Br. R. A. S., Vol. V, and Geological Papers on Western India, p. 638.

† Jour., Bombay Br. R. A. S., Vol. VI, p. 161.

‡ Jour., Roy., Geog. Soc., 1870, Vol. XL, p. 181.

§ Jour. A. S. B., 1876, XLV, Pt. 2, p. 86.

Umarkot to Bálmír.—From Umarkot to Godra (60 miles) the road is over sandhills, with the same general strike north-east—south-west; but towards Godra the hills decrease in number, and sandy plains intervene. For about 35 miles from Umarkot, all well-water is very brackish, the wells being in sandy clay; farther to the eastward, although no rock is seen at the surface, sandstone is found at a little depth, and sweet water is procured. The edge of the sandstone may mark the limit of the old estuary, and hence the brackishness of the water to the westward.

Sandstone is also seen in some tanks near Godra. It is fine, whitish or pinkish in colour, rather felspathic, soft and often nodular from containing concretions of carbonate of lime. From a well in Godra, besides the sandstone, pinkish clay, a gritty ferruginous rock resembling laterite, and compact gritty limestone have been procured. No fossils were found, and it is difficult to ascertain what the beds can be. They may be either Jurassic or Tertiary, the former being perhaps rather more probable.

Near Rámsir, 15 miles east of Godra, hills of hard rock begin to appear, at first isolated and of small extent, but farther to the eastward forming ranges of considerable height. These hills are chiefly composed of a very hard felsite-porphyry, dark-coloured and closely resembling jasper in texture. In some places, as at Redano hill, and again at Jessai, coarsely crystalline granitoid syenite and pegmatite are associated with the felsite. These felsites and their associates may be called for convenience Maláni beds.*

These rocks continue as far as Bálmír, and extend for a considerable distance north and south of the road. The town of Bálmír is built partly at the base, partly on the slope of a hill, which, like several others to the northward, consists of sandstones, resting upon the dark-coloured felsites. At the base of the formation is a coarse conglomerate of felsite pebbles; above this are whitish and grey sandstones, sometimes very compact and hard, but elsewhere softer and veined or blotched with purple. A few ill-marked plant remains occur in these rocks.

These beds dip at 20° to 25° to the north-east on Bálmír hill, a small outlier occurring on the top of the highest hill, a trigonometrical station. The same rocks continue for a mile, or rather more, along the edge of the hills to the northward, and re-appear in some isolated hills in the sandy plain north-north-west of Bálmír, the farthest observed being five or six miles from the town. Some of the sandstones are used for building, and are well adapted for the purpose.

North and east of Bálmír is a great sandy plain with occasional sandhills. At a village called Kapúlí, 12 miles to the north, a very fine unctuous clay resembling fuller's earth is found and quarried to some extent. It is associated with hard buff shale and some calcareous grit. The beds roll about at angles of 15° to 20° and may belong to the same group as the Bálmír sandstones. A calcareous conglomerate is exposed about the village of Mohábar, 3 miles south-south-east of Bálmír, and fragments of similar rock are seen north of the town, about the tanks. This conglomerate contains pebbles both of the Maláni felsites and of the Bálmír sandstone and is probably of late origin.

Bálmír to Jodhpúr.—At Sáokar, eight miles east of Bálmír, much calcareous tufa occurs, apparently deposited from springs. The water at the village is very hard, evidently containing lime, and so brackish as to be unfit for drinking. No solid rock is seen in place for 30 miles east of Bálmír, on the road to Jasol, with the exception of this calcareous tufa.

* Maláni is the name of the district of which Bálmír is the chief town. It belongs to Jodhpúr but is at present under British management.

The sandhills increase in number to the eastward; they are not arranged in long north-east—south-west ridges as near Umarkot, but in more irregularly formed rises, always steeply scarped to the north-east, and often shewing evidence of considerable denudation from rain.

Three miles before reaching Náosir, some sandstone is seen, precisely like that of Bálmír, but dipping at low angles. The same rock forms hills to the south near Sárun and Sanpha. The first-named ridge extends for some miles, the beds dipping about south-40°-east, towards an exposure of diorite, which is probably a member of the Maláni beds. Porphyritic felsite is seen on both sides of the Sanpha hill, to the east and to the west. The relations of these different outcrops is not very clear; but for the occurrence of felsite west of Sanpha hill, it might be supposed that the broad tract from Bálmír to Náosir is occupied by the Jurassic rocks of which the Bálmír sandstones, as will hereafter be shewn, are the base, but the ground requires further examination.

At Náosir a variety of felsite occurs which is very quartzose and of a reddish colour. almost resembling red quartzite in places. The usual dark-coloured porphyry with red felspar crystals is exposed at the Lúni river and forms the range of hills south of Jasol. The large hills to the south-east in the direction of Jallor are probably of the same rock, which may extend as far as the Arvali range.

North of the Lúni river near Jasol, a somewhat depressed plain, in the neighbourhood of the town of Pánchbhadra, has long been the seat of an extensive manufacture of salt, The tract is much covered with sand, but is lower than the surrounding country, and may be the site of an ancient salt lake, or of a tract of low country covered at one time by the sea, if an inlet extended up the Lúni valley. The salt is obtained from pits into which brine trickles, and is evaporated by the heat of the sun.

For many miles below Jasol no rock is seen in the bed of the Lúni river, and there is a flat alluvial plain south of the river, which here runs east and west. At Jasol some coarse conglomerate, found on the bank of the stream and used for building, is apparently a sub-recent formation. From Jasol to Jodhpúr, a distance of 60 miles, the whole country appears to be alluvial; no rock is met with, except in a few isolated hills, all of which consist of the Maláni felsites.

These felsite-porphyries and their associates, here varying more than usual in character, and comprising beds which unmistakably resemble volcanic ash, are well developed at Jodhpúr, and the greater portion of the town itself is built upon them. The commonest variety is a brownish-red porphyry with the usual red felspar crystals, the ash beds being well seen about three miles south-west of the town.

Jodhpúr sandstones.—The long ranges of low flat-topped hills, however, which extend for many miles south-west, west, and north of Jodhpúr, consist of red sandstone, which may perhaps be of Vindhyan age. It is certainly quite distinct from the sandstones of Bálmír, and appears to be older. It is, as a rule, rather coarse, often obliquely laminated, and it frequently contains small pebbles. It is largely used as a building stone; some kinds bear carving, and its resistance to the destructive effects of exposure is amply proved by various old buildings in the neighbourhood of Jodhpúr.

The Maláni felsites only occupy the town itself and a patch of ground extending three or four miles to the south-west and north-east, the sandstones resting upon them to the north-west, and a sandstone outlier forming the fort of Jodhpúr itself. The sandstones are quite unconformable to the felsites. To the east and south-east of the town is a broad sandy

alluvial plain. In this plain between one and two miles east-north-east of the fort, shale, pale-greenish and dark-red in colour, is found in wells. The relations of this shale are obscure; it may belong to the sandstone group.

III.—Route from Jodhpūr to Rohri via Pokran.

Jodhpúr to Pokran.—On the road leaving Jodhpúr in a west-north-west direction red sandstones are seen at intervals as far as Lowo, a distance of 80 miles. Two small exposures of Maláni beds were observed near Jodhpúr, one near the village of Palrí, eight miles north of the town, the other in a stream-bed, 4 miles farther north, near Managrá. The sandstones are well seen to beyond Tiyúrí, 20 miles north-west of Jodhpúr, rising into low hills: and similar rises extend nearly twice as far in a direction a little north of west; but from Tiyúrí to Lowo rocks are only seen at rare intervals, the country consisting of sandhills with broad sandy flats intervening between them. The sandhills continue for about 40 miles, and then gradually becomes lower, less extensive, and more distant from each other, until they finally disappear between Dechú and Mandlo. They have no definite arrangement in ridges, but present, as usual, steep scarps to the north-east.

It is impossible to say whether the Jodhpúr sandstones continue throughout the area beneath the sand. They appear here and there, and the only other rock seen was some shale of a greenish colour which is exposed in a tank just west of Dechú, 60 miles from Jodhpúr, and may belong to some beds better seen at Lowo. Beyond Mandlo the country is very flat, and some portions, which appear to be depressed below the general level, form salt plains. Three of these are passed between Mandlo and Pokran, one at Daidia, a second north of Lowo, and the third, which is by far the largest, a few miles east of Pokran. The origin of these plains is very obscure: they may have originated in changes of level, though there is a possibility of their being portions of old valleys dammed up by sand. When rain falls, water accumulates in them to a small extent, and, evaporating, leaves a thin crust of salt. Similar salt plains were seen near Rodano hill, west of Bálmír. The amount of denudation from rain in this region must be singularly small, or such shallow depressions would be filled up.

The red Jodhpúr sandstone is seen east and west of the Daidia plain, and it forms a continuous low scarp to the north of the plains at Lowo and Pokran. But at Lowo itself some peculiar gritty and sandy shales are seen, mostly hard and sometimes porcellanic, of various shades of red and green, and containing in places pebbles and boulders of all sizes up to many feet in diameter, composed of felstone porphyry and granitoid syenite, all apparently derived from the Maláni beds. These shales stretch across towards Pokran, where they occur to the south and west of the town. About half way from Lowo to Pokran there is a considerable outburst of basalt, the relations of which are not clear, no similar rock having been found associated with the volcanic Maláni beds.

The town of Pokran appears to be built upon sandstone, but the rock is badly seen, and is cut up by veins of calcareous tufa. To the north the same rock forms a low escarpment; whilst south, west, and south-east of the town volcanic rocks occur, clearly belonging to the Maláni porphyries, and consisting of felsite of various colours, often pale-green or slate-coloured, with, in places, grains of transparent quartz and the characteristic felspar crystals. In many places these rocks have a distinctly stratified appearance, due probably to imperfect cleavage.

Upon the volcanic rocks rests, in places, a thick deposit of boulders derived from them, in a matrix of coarse red grit. Green shales, precisely like those of Lowo, are associated with this boulder bed, which contains rounded fragments of all sizes up to two feet in diameter. At one spot, a short mile south-west-by-west of Pokran, where the surface of the porphyry, underlying the boulder-bed, was exposed, it was unusually smooth and distinctly striated, the

striæ running north-east—south-west. This is strongly confirmative of the probability of glàcial action having contributed to the transport of the large boulders seen at Lowo. It should, however, be mentioned that the boulders seen near Pokran were all rounded, and none exceeded the dimensions often carried down by an ordinary stream.

About a mile north-west of Pokran, in some ravines, the sandstones are seen abutting against both Maláni beds and shales, and apparently resting unconformably upon both.

Pokran to Jesalmír.—From Pokran to Láthí, the country is a sandy plain in which rock appears at but few places, and is even then very ill seen. The few exposures which occur belong to various groups, and it is often difficult to assign them with any certainty. Four miles west of Pokran, volcanic rocks (Maláni beds) are exposed in a tank, and a few fragments seen on the road-side further west are probably the same. About nine or ten miles from Pokran, red sandstone is seen in place; but it is conglomeratic, and does not resemble the Jodhpúr beds. Near Odhania some old-looking impure limestone occurs, of various colours, yellow, brown, slatey, white, &c., associated with whitish quartzite. Some of the limestone resembles that of the Lower Vindhyans.

At Odhania itself grey shaley sandstones are seen in a tank east of the village, whilst to the north-west massive greyish and white sandstone and grit are exposed, and quartz pebbles scattered over the surface indicate the presence of conglomerate. These beds differ from anything previously seen and probably belong to the Jurassic series. West and south-west of Odhania fragments of diorite and porphyry occur, containing, besides felspar, hornblend or augite crystals; and, about half a mile west of the village, fine grained syenite is seen in place. These rocks evidently belong to the Maláni series.

On a rise two miles west-20°-north of Odhania, scattered fragments of white quartzite are seen; then, half a mile farther west, a conglomerate is exposed of various pebbles, chiefly felsite, in a matrix of red grit. This bed precisely resembles the boulder-bed of Pokran. Half a mile farther quartzite recurs; it is finely laminated and white or grey in colour. This was the last exposure of the older beds noticed. The quartzites and old limestones may belong to the same series as the shales and boulder-beds of Lowo and Pokran, but nothing can be determined from the very poor exposures seen.

About four miles before reaching Láthí, dark-brown, hard ferruginous sandstone is seen, resembling the "iron bands" of the Máhádéva and Kámthi beds, and the same reappears a mile further on a rise to the north of the road. This rock belongs to the lower portion of the Jurassic beds. For a mile or two before reaching Láthí, and for about the same distance west of the village, soft whitish and reddish sandstones are exposed in a hollow, which has been the bed of a stream. The beds are nearly horizontal; they abound in fragmentary vegetable remains, none of which, however, can be identified. Large blocks of silicified wood occur unrolled; none of the larger fragments were seen in place, but smaller pieces, less well preserved, are embedded in the sandstone.

For many miles west of Láthí there is the same sandy plain as to the eastward rocks being only seen at very few places, as at Sodakhor, six miles west of Láthí, where calcareous conglomerate with sandstone pebbles, grey sandstone, and black ferruginous sandstone occur; nothing more is seen for twelve miles. Near Sháwal a low scarp is crossed, consisting of the same grey sandstone, with hard blackish ferruginous bands; and this scarp can be traced for a long distance to the southward. A little farther west yellowish-brown limestone crops out, weathering red and containing fossils, apparently *Gasteropoda.* The succession of low scarps dipping westward shews that an ascending series of beds is traversed, the westwardly dip being, however, very low.

Neighbourhood of Jesalmír.—Three or four miles north-west of Hanúra, a higher scarp of buff-coloured limestone is reached; it rests upon sandstone, and this scarp extends to Jesalmír. Above the scarp the ground is rocky, and a second scarp of very similar limestone and sandstone exists at a short distance from the first. Some of the sandstone is very hard and vitreous. The beds have a low dip to the northward, and six or eight miles farther in that direction another scarp of rocks, higher in the series, is seen.

Jesalmír is at the base of the lower scarp, the fort being built upon a detached outlier. The same scarp extends for some distance to the west, then turns south-west. It can be traced about six miles from the town, the beds throughout being the same buff compact sandstone, resting on whiter calcareous beds, and these again on grey sandstones with occasional ferruginous bands. Six miles from Jesalmír, near a stream-bed called Kákana, the rocks begin to roll about, but they are said to be traced some six miles farther, to a village called Mohar, before being covered up by the sand of the Thar. The surface of the limestone above the scarp is very distinctly striated by the action of sand driven by the wind, the striæ running about north-35°-east. The limestone abounds in marine fossils of Jurassic age.

The limestone is an admirable building stone, and is largely quarried. Jesalmír is built of it; and slabs are exported all over the country for temples, tombstones, &c., some having been taken even as far as Sind. It is used for fine carving, some of the pieces which have been taken to Sind having elaborate Arabic inscriptions cut upon them; it is of uniform texture and very fine grain, and it resists the action of the weather well.

The rocks south and south-east of Jesalmír are much better exposed than to the eastward, and are seen in descending sequence as far as Kíta, a distance of about fifteen mlies, all having a low dip, usually less than 1°, and never exceeding 2°, to the north-west. From Kíta to Vinjorai all the country is said to be covered with sandhills. At Vinjorai it is said that peaked hills occur; these may consist of the Maláni porphyries. The beds seen between Jesalmír and Kíta are doubtless identical with those between Jesalmír and Láthí: for the first ten miles they consist of a succession of limestone beds interstratified with sandstones. Just south-west of the fort at Jesalmír there is a low scarp of impure brown limestone resting on soft grey sandstone. Below this again, south-by-east of the fort, and south of a large tank, some hard grey limestone is found, abounding in small shells; it is quarried to a small extent for ornamental purposes. It contains fragments of buff limestone and pale-yellow calcareous shale. Beneath these beds occurs a succession of brown limestones, brown and grey sandstones, often calcareous, ferruginous sandstones, dark-brown or blackish in colour, and conglomerate, containing pebbles of quartzite, red jasper, and ferruginous sandstone, the last precisely like that found in the beds beneath all the limestones. Other conglomerates contain fragments of grey sandstone and ill preserved fossil wood, mixed with ferruginous nodules, in a yellowish calcareous matrix.

The lowest band of limestone forms a well-marked scarp, which is seen extending for many miles to the south-west. Beneath it soft grey sandstones, with hard brown or black ferruginous beds, prevail, all dipping slightly to the north-west. At Kíta soft, white and variegated sandstones occur, the former in every respect resembling the beds of Láthí, and, like them, containing in abundance indistinct vegetable fragments. In places these fine, white, rather micaceous beds are stained with lilac, purple and scarlet in irregular veins and blotches, and they then are much like some of the Bálmír sandstones, except in being softer. It is not seen on what these rocks rest. To the south-east, in which direction lower beds might be found, all the country is covered with sand-hills.

Jesalmír to Rohrí.—The country to the north of Jesalmír was not examined. Limestone is said to extend in this direction for about fifteen miles. Westward, on the road to Rohrí, the Jesalmír limestone bed is traversed for seven or eight miles, then after two miles of sandy plain, some low hills are crossed, consisting of calcareous sandstone, partly whitish, partly dark-coloured, with a little limestone. These beds appear to overlie the Jesalmír limestone. The next rocks seen form a low ridge north-west of Chitrail, about fourteen miles from Jesalmír, and consist of blackish ferruginous sandstone, dark-brown calcareous sandstone, whitish calcareous sandstone—which weathers into heaps of fantastic forms, resembling bones or stems of trees—yellow and buff sandstones, and white sands, streaked and variegated with purple. These beds have a low north-west dip, less than 1° in general, and consequently they appear to overlie the beds of Jesalmír. Very little rock is seen for ten or twelve miles to the westward, the little which is seen being similar to that near Chitrail.

A mile west of Kuchrí, twelve miles from Chitrail, another low scarp appears, consisting of dark calcareous sandstone resting upon soft, white sandstone. On the top of the scarp there is a band of buff and brownish limestone, sometimes changing to red where exposed, and abounding in *Ammonites* of three or four kinds: an *Arca* and other bivalves also occurring, and there is a bed of oysters. It was a fragment of this rock, brought by Dr. Impey, which was examined by Dr. Carter, and recognized as of Jurassic age.

These beds have a low dip to west-north-west. In the valley to the westward, some soft grey sandstone of the usual Jurassic character is seen, with, as usual, hard ferruginous beds interstratified. West of this again, four or five miles from Kuchrí, is a steep scarp of Nummulitic limestone, resting on the Jurassic beds. The junction is clearly unconformable, although the unconformity is not marked and the bedding of the two formations is nearly parallel. On the top of the scarp is a bed of the rock characteristic of the Khirthar limestone weathering with a rugged nodular rubbly surface, and containing *Nummulites Ramondi*, *N. Leymeriei?* and *N. Beaumonti*. Below this are softer yellowish beds, and near the base are some greenish and buff shales, associated with an impure limestone containing *N. Spira*. This band, doubtless, represents the lowest bed in the Rohrí hills, in which *N. Spira* is especially abundant. No trace of the green clays seen below the limestone of the Rohrí hills, or of any of the infra-Nummulitic and cretaceous beds of Sind, could be recognized.

The scarp extends for many miles to the north-east; to the south-west it is covered by sand-hills. Westward the limestone extends for about two miles beyond Kuyálá, or between four and five miles altogether, and patches occur beyond; at first at short intervals; but after three or four miles, no more are met with until one is seen amongst the sand-hills about seventeen miles from Kuyálá, and another halfway between Asú and Gotarú. About five miles west of Kuyálá, near some wells called Bánda, there is an inlier of buff limestones and ferruginous sandstone, evidently belonging to the Jurassic rocks, surrounded by nummulitic limestone.

On the road which passes through Asú, sand-hills begin to cover the ground completely about six or seven miles before reaching that village, which is twenty-two miles from Kuyálá, and they continue thence for the greater part of the distance to Rohrí. Near Asú and Gotarú, they are arranged in long ridges, having a general direction of about north-20°-east to south-20°-west; but towards Mitráhú, the first place where fresh water occurs within the Sind frontier, the regular ridges cease and irregular hills occur, often scarped steeply to the north-north-east. Alluvial tracts and marshes appear between the hills, and the country is within the limits of the Indus alluvium.

IV.—SUMMARY OF GEOLOGICAL OBSERVATIONS.

Formations observed.—From the preceding account of the journey, it will be seen that in the tract traversed the following formations were distinctly identified:—

9.	Blown sand	Post tertiary.
8.	Alluvial deposits	Post tertiary.
7.	Nummulitic limestone	*Tertiary.*
6.	Ammonitiferous beds of Kuchri	*Jurassic.*
5.	Jesalmír limestones and sandstones	*Jurassic.*
4.	Bálmír sandstones	*Jurassic.*
3.	Jodhpúr sandstones...	? *Vindhyan.*
2.	Shales and boulder bed of Lowo and Pokran ...	?
1.	Maláni felsite, porphyries, syenite, &c.	?

Maláni beds.—It is evident that these, the oldest rocks met with in the portion of the desert traversed, are volcanic. Their extremely silicious nature may be due to alteration but their porphyritic character, and the occasional occurrence of ash beds, sufficiently attest their volcanic origin. They consist principally of very silicious felsites, so hard that they are not scratched by quartz, and have frequently the appearance and texture of jasper. They vary greatly in colour, from black or dark-drown to pink, blue or white, the dark-coloured rock being always hard and undecomposed, whilst the lighter-coloured varieties are softer and appear to be altered. The most constant character is the presence of small crystals of felspar, usually of a pink or red colour, in addition to which small grains of transparent silica are frequently dissiminated throughout the rock.

In places diorite was found associated with these rocks, and in some of the hills west of Bálmír, coarsely crystalline granitoid syenite and pegmatite are intercalated in large masses with the porphyritic felsites. True granite may occur, but in the few hills examined mica was absent, although the character of the rock was distinctly granitic. The presence of similar granitoid rocks elsewhere is rendered probable by the occurrence of pebbles and boulders in some of the later beds.

The Maláni rocks must be very ancient, but no idea can be formed of their geological position, as they are nowhere associated with rocks of known age except where underlying beds of comparatively recent date, and nothing resembling them appears hitherto to have been detected elsewhere in India. They form the hills extending upwards of 30 miles west of Bálmír, and south as far as Chotan, 25 miles south-west of Bálmír, and north probably to Vinjorai, 35 miles south-south-east of Jesalmír. South of the Bálmír hills, no rocks are known to occur for a considerable distance, but the syenite hills of Nagar Párkar, which are in this direction, may probably belong to the Maláni series. To the eastward of Bálmír no rocks are seen for 30 miles, but the porphyritic felsites are extensively developed on the Lúni river for many miles below Jasol and Pánchbhadra; they appear to form a portion at least of the high hills south-west of Jasol, towards Jallor, they constitute the few rocky hills which rise out of the sandy plain between Pánchbhadra and Jodhpúr, and they reappear at Jodhpúr itself, where some of the beds are unmistakable volcanic ash. On the road from Jodhpúr to Jesalmír, their presence, except near Jodhpúr, was only detected in the neighbourhood of Pokran.

2. *Shales of Lowo and Pokran.*—The next series of beds in ascending order consists of peculiar green, red, and variously coloured shales, occasionally soft, but often hard and even porcellanic. Some are fine, others are coarse and sandy, and contain grains of pink felspar, and of a green mineral resembling epidote; some beds being composed throughout of one or the other of these minerals. In places, pebbles and boulders of the Maláni porphyries and syenite are found towards the base of these shales; the boulders being occasionally

from three to four feet in diameter, whilst remains of much larger blocks, which had fallen to pieces, but which could not have measured less originally than twelve to fifteen feet in diameter, were seen about Lowo. These boulders appear to have been brought from a distance, and there is some reason for supposing that they may have been transported by ice, as the underlying surface of the Maláni porphyries near Pokran was in one instance found to be grooved and striated.

These beds also can be identified with no known Indian formation. The shales were found around Lowo and Pokran, and some quartzites, limestones, &c., of ancient appearance, but which are very ill seen in places west of Pokran, may belong to the same series. Some shales which were observed in a tank at Dechú, 60 miles west-north-west of Jodhpúr, and about 30 east-south-east of Pokran, may be the same. Some softer shales which occur at Jodhpúr should more probably be referred to the next group.

3. *Jodhpúr sandstones.*—The sandstones which cover a considerable tract of country in the neighbourhood of Jodhpúr are usually coarse in texture and almost always dull red in colour, though occasionally white or brown. As a rule, they are purely quartzose, but they sometimes contain felspar, and in places they are highly micaceous, the mica being arranged in layers, so as to produce a shaley structure. Small pebbles occasionally occur and are chiefly composed of quartz, but the rock is not usually conglomeratic; it is, however, often obliquely laminated, and the surfaces of slabs are frequently ripple-marked. The beds are quite unaltered and often nearly horizontal, rolling about at low angles.

Except for their being rather softer, there is little, if anything, to distinguish these sandstones from some of those belonging to the Vindhyan series. No rocks of this series have hitherto been detected west of the Arvali hills, the great Vindhyan area commencing several miles to the eastward of that range. The reference of the Jodhpúr sandstones to the Vindhyans is little more than a suggestion; they resemble the beds of that series more than any other known Indian formation, but it is quite possible that they may belong to a different horizon.

The Jodhpúr sandstones were not noticed south-west of Jodhpúr. They are found for some distance west of the town and for many miles to the northward, their extent in this direction being quite unknown. They are found stretching from Jodhpúr to Pokran, a distance of 90 miles, but much of the intervening country is so completely concealed by sand, that it is impossible to say whether any breaks occur.

4. *Bálmír sandstones.*—The next three groups belong in all probability to the Jurassic series; marine Jurassic fossils being found abundantly in the two upper. At Bálmír and in some hills to the eastward a considerable thickness of sandstones, grits and conglomerates is exposed, the characteristic beds being whitish or grey sandstone, very fine and compact, so compact indeed as to break with a sharp conchoidal fracture, and to have a sub-vitreous lustre on the fractured surface. With these beds coarser and finer sandstones are associated, the finer passing into a compact hard shale, whitish in colour, but sometimes veined and blotched with purple, and at times entirely purple. There are also bands of coarse conglomerate towards the base, containing, at Bálmír, pebbles of the underlying Maláni beds. A few fragmentary remains of plants were found in these beds, but none sufficiently well preserved to be determined with certainty.

Similar rocks, rather less hard, occur near Náosir, Sanpha and Sárun, 30 miles east of Bálmír, the intervening ground being concealed by sand-hills.

East and south-east of Jesalmír, beneath the marine Jurassic beds of the next group, a considerable thickness is exposed of grey, white, and brown sandstones, interstratified with numerous bands of hard black and brown ferruginous sandstone and grit. The base of these

beds is not seen, but the lowest strata exposed at Kita, 15 miles from Jesalmír, on the road to Bálmír, are fine white beds, soft, argillaceous, and slightly micaceous, and stained purple, lilac and scarlet in places. Some of these beds so closely resemble the variegated sandstones of Bálmír that it is probable they are of the same age, and their much greater softness may be due to the smaller amount of disturbance they have undergone. Precisely similar soft white sandstones are found at Láthí, 40 miles east-by-north from Jesalmír, and are doubtless on the same horizon as those of Kíta: at both places fragmentary plant remains are common, but nothing recognizable could be found except some dicotyledonous fossil wood, which occurs at Láthí.

These rocks resemble the Umia beds of Cutch, and they are very similar to some Gondwána rocks, especially portions of the Kámthí and Máhádéva groups.

5. *Jesalmír limestones.*—Above the beds last mentioned are the Jurassic limestones and sandstones of Jesalmír. These consist of sandstones with thick bands of compact, buff and light-brown limestones, one of the most beautiful building-stones in India, and of which much use might be made if it were more accessible. The sandstones vary much, being grey, brown and blackish (ferruginous), sometimes calcareous, and occasionally interstratified with bands of conglomerate, containing pebbles of quartzite, red jasper, and ferruginous sandstone, the last of which looks as if derived from the underlying group. Some other forms of limestone occur, and in one place a grey rock abounding in shells is found.

The limestones contain numerous fossils. Specimens of *Ammonites* (*Stephanoceras*) *fissus*, Sow., were obtained from the natives at Jesalmír, but the exact locality could not be determined; there can be little doubt, however, of its being in the neighbourhood of the town. I found the following species in the limestone scarps; for the determination of several of them I am indebted to Dr. Feistmantel:—

ECHINODERMATA.

Hemicidaris, sp.
Pygurus, sp.

MOLLUSCOIDA.

Terebratula biplicata, Sow.
T. intermedia, Snow.
Rhynconella, sp.

MOLLUSCA.

Mactromya, tp. common.
Homomya, 2 sp.
Pholadomya granosa, Sow.
Corbula lyrata, Sow., common.
C. pectinata, Sow , common.
Trigonia costata, Sow.
Nucula cuneiformis, Sow.
Modiola, sp.
Pinna, sp.
Pecten lens, Sow.
Anomia, sp.
Nerinæa, 2 sp,
Natica, 2 *or* 3 sp.
Nautilus Kumagunensis, Waagen.

Many of these are characteristic Jurassic forms, and are found in the Oolitic rocks of Cutch; the two *Cephalopoda*, *Ammonites fissus* and *Nautilus Kumagunensis*, being met with in the Chárí group.

Above the limestones of Jesalmír, sandstones of various colours, frequently calcareous, are seen, but they are not so well exposed as the beds below the limestones, and it is difficult to say whether these upper strata should be assigned to this group or the next.

No unconformity could be detected between the Jesalmír beds and the underlying sandstones which are supposed to represent the Bálmír rocks. The lowest beds of the former are seen in a scarp a few miles south-east of Jesalmír. At the same time the examination made was necessarily cursory, and the existence of a break is rendered probable by the occurrence of pebbles, apparently derived from the lower group, in the conglomerates of the upper.

6. *Ammonite bed of Kuchrí.*—At Kuchrí, two short marches, or about 25 miles west-north-west of Jesalmír, a belt of rocks appears, consisting of dark calcareous sandstones resting on soft white sandstone, and capped by a thin bed of buff and brownish limestone, weathering red where exposed, and abounding in *Ammonites* of a yellow colour, belonging to three or four species, an *Arca*, oysters and other bivalves. None of the *Ammonites* appear to be Cutch species, though one form is near *A. opis*, Sow. Above the limestone is some grey sandstone with hard ferruginous bands of the usual Jurassic character, and upon these beds rests nummulitic limestone.

The relations of the Kuchrí beds to those of Jesalmír is not quite clear, but apparently the former are higher in the series. Still, as no rocks are seen over a considerable proportion of the intervening country, there may be a concealed roll of the strata, or a fault, but it is more probable that the beds are nearly horizontal, with a gradual ascending sequence to the north-west, and unfaulted, because any kind of disturbance would tend to harden the beds and enable them, by resisting denudation, to stand up above the surface.

7. *Nummulitic limestone.*—This was only seen west of Kuchrí. It appears to represent the lowest beds of the Khirthar group at Rohrí, and it rests directly on the Jurassic rocks, no representatives of the lower Eocene (infra-nummulitic or Ranikot group), Deccan traps, or Cretaceous beds of Sind and Cutch being met with.*

8. *Alluvial deposits.*—Exclusive of the Indus alluvium, a large portion of the desert appears to be covered with deep alluvial deposits. This is especially the case in the Lúni valley, and the country south-west of Jodhpúr, but large tracts between Godra and Bálmír, others east of Bálmír, and between Jesalmír* and Pokran, are thickly covered with a sandy deposit, which is doubtless at the surface a comparatively recent formation. Many of these tracts are covered with blown sand, and the wash from the sand-hills is spread over the surface and cannot be distinguished from older sandy deposits. Much of the alluvium, however, appears to be of older date than the blown sand, and to have covered the surface before the sand-hills were formed.

9. *Blown sand.*—An immense area of country is entirely covered with sand-hills, and tracts of blown sand are to be found in numerous places from the banks of the Indus to the Arvali range. Besides the more isolated hills scattered over the country, there are two tracts in especial, in the area traversed between Sind and Jodhpúr, in which the surface is entirely covered with blown sand. One of these, which is known as the Thar, is in eastern Sind, along the edge of the Indus alluvium, and it extends the whole length of

* I have since seen fragments of the same limestone said to have been brought from south of Jesalmír, the locality being probably near Vinjorai.

the province, from the Ran of Cutch to the Baháwalpùr territory. The other tract extends northward or north-north-east, also from the neighbourhood of the Ran, and was crossed east of Bálmír, and again between Jodhpùr and Pokran. It appears to extend towards Bikanìr.

The hills in the western tract are arranged in regular parallel or nearly parallel ridges running nearly north-east and south-west to the southward near Umarkot, while further north, towards Rohrí, they have a direction from south-south-west to north-north-east. The ridges frequently end abruptly with a steep slope to the north-east.

Elsewhere the sandhills are not arranged in parallel ridges, but are more or less thickly scattered over the surface, and have always a steep slope to the north-east and a long gentle slope to the south-west. It is evident that the sand has been transported and deposited by the strong south-west winds of the hot season—May, June, and July. The origin of the parallel ridges is much more obscure, but there can be very little doubt of their being due to the south-west wind*.

The sand consists chiefly of rounded quartz grains, felspar, hornblend and one or two other minerals being also present in small quantities. A portion of it may be derived from the Indus, but a far larger proportion must be due to some other source. Many of the sand-hills are evidently of great antiquity; despite the small rainfall of the desert region, they show signs of considerable denudation in parts, and are cut into deep ravines by the action of water.

It is highly probable that the Ran of Cutch is an old inlet of the sea, which has been filled up by the sediment brought in by the Lúni and other rivers. The presence of a marine mollusk, living in the salt-lakes north of Umarkot, proves that this inlet extended far up the Indus valley, and the great saltness of the soil, both in the Thar and in the Lúni valley, suggest the probability of the sea having extended in both directions. The shore of this great inlet may easily have supplied the blown sand which now covers so large an area of the desert, and the distribution of the sand-hills nearly coincides with what might be expected if the sands were derived from such a source.

Throughout the greater portion of the desert there is no evidence of marine denudation. Nothing of the kind is seen neer Bàlmìr, and the scarps near Jesalmír are evidently due to subaërial action, and quite different in appearance from sea cliffs, each being formed by the outcrop of a hard bed. It therefore appears probable that the central region of the desert was above the sea, forming either a promontory or an island, whilst the Ran of Cutch, the Indus valley, and portions of the Lùni valley were under water.

ON THE OCCURRENCE OF THE CRETACEOUS GENUS OMPHALIA NEAR NAMCHO LAKE, TIBET, *about 75 miles north of Lhassa. By* OTTOKAR FEISTMANTEL, M. D.; *Geological Survey of India.*

Last year (1876) the Geological Survey received some fossils from Captain Trotter, which were collected by one of the Pandits attached to the Trigonometrical Survey of India on his route from Ladak (Leh) to Lhassa.†

The most peculiar amongst them appeared to Mr. W T. Blanford, who first received this collection, and subsequently to me, some *Turritella*-like forms, which were especially characterised by two well-marked, prominent ribs in each whorl (in the whole height of the

* See for further details J. A. S. B., 1876, XLV, Pt. II, pp 92,67, &c.

† See sketch-map in Geographical Magazine, June 1876.

shell), by an angular (sinuated) striation of the shell in each whorl, and by the thickness of the shell. The specimens were labelled "Hills near Namcho Lake, Tibet." Other work, especially on the different local floras of India, compelled me to delay the determination for a future occasion.

When later the palæontological collections of the Asiatic Society of Bengal were amalgamated with those of the Survey in the Indian Museum, I found amongst them a much better preserved specimen of the same kind as mentioned above; but no locality was attached, only the inscription "Glauconia" sp.?

This discovery induced me to return to the examination of the Pandit's fossils, and they yielded the interesting result that the fossils belong to that genus, which was established first by Zekeli in his paper on "Gasteropoda of the Gosau formation, 1852" with the name *Omphalia*, Zek., with which *Glauconia*, Gieb., is synonymous.

Family: TURRITELLIDÆ.

GENUS.—OMPHALIA, *Zekeli*, 1852.

1852. Zekeli Gasteropoden der Gosaugebilde, Abhandl., der k.k., Geolog. Reichsanstalt Wien—1852.

1852. *Glauconia*, Giebel allgemeine Palæontologie, p. 185.

1853. *Omphalia*, Reuss: Kritische Bemerkungen über die von Hern Zekeli beschriebenen Gasteropoden der Gosaugebilde in den Ostalpen. Sitzb. der k, Academ, der Wissensch, Vol. XI, p. 7.

1853. *Idem*, Abstract in Leonhard and Bronn N. Jahrb. f. Mineral, etc., p. 635.

1842-43. *Turritella*, ex parte D'Orbigny, Pal. francaise Gasteropodes, Terrain crétacés, Vol. II. Pl. 152, 153.

1863. *Omphalia*, 3 new species, Drescher Uber die Kreidebildungun der Gegend von Löwenberg, Zeitschr. d. D. Geolg. Gesellsch, 1863, p. 334, Pl. IX, f. 2-7.

1865. *Omphalia*, Dr. Stoliczka,—Eine Revision der Gasteropoden der Gosauschichten in den Ostalpen. Sitzb. d. k. Acad. d. Wiss. in Wien., 1863, p. 11.

1865. *Cassiope*, (replacing or including *Omphalia*, Zekeli) Coquand, Monograph de l'étage Aptien de l'Espagne, p. 57, Pl. III, IV.

1867. *Glauconia*, Stoliczka, Gasteropoda of the cretaceous rocks of Southern India, Pal. Indica, vol. v., 1867, p. 209, et sequ.

I think I am right, using the generic name *Omphalia*, as Zekeli established it, and not *Glauconia*, Giebel, which was published, it is true, in the same year, but Zekeli's paper was presented already, partly at least, in 1851, although published only in 1852.

Prof. Reuss and Dr. Stoliczka, in their papers 1853 and 1865, did the same, only in 1868 Dr. Stoliczka adopted, in contrast with his paper of 1865, the genus *Glauconia*, including *Omphalia*, Zek.

Quite unnecessarily and superfluously M. Coquand, 1865 (l. c.), established a quite new genus *Cassiope*, uniting with it, without sufficient grounds, Zekeli's *Omphalia*. Zekeli first gave most figures of this genus, and so his name is to be used by all means.

The characters of the genus are the following:—

"The shell is always shortly conoidal or turreted, very thick, with spiral ridges or ribs; the columella generally hollow, aperture round-ovate; the exterior lip with two emarginations, of which one lies above, or rarer in the middle of the right labial margin, the other on the base. The striæ of growth are sinuated (waved) according to the emargination."

As to the systematical place, it seems that *Omphalia* is mostly related with the *Turritellidæ,* although it presents also some similarity with the *Melanidæ,* and Dr. Stoliczka l. c. p. 211 (1867) considers it as a truly intermediate form between these two families, although he describes it at the beginning of the *Turritellidæ.*

The difference from *Cerithium* is established by the form of the aperture and the complete want of any canal to the aperture.

In Leonhard and Bronn N. Jahrb. (1853) p. 636, a relation with *Nerinea* is mentioned as possible. But *Nerinea* has such a constant appearance in the faults on the columella and in the more rhomboidal aperture, that forms of it can scarcely be mistaken.

Also in comparison with *Turritella* there are differences enough. The shell of *Turritella* is always higher and more accuminate, thinner, has no real columella and an emargination in the exterior lip is not constant, and when present, always shallower and the striæ of growth therefore are never so waved.

As to the "conditions of living" of the *Omphaliæ,* Dr. Stoliczka already, in his revision of the Gosau Gasteropoda (l. c., p. 15), stated that the *Omphaliæ* in the Alps are characteristic of coal-bearing strata,—and he concludes that they appear to be inhabitants of brackish or fresh water (Pal. Ind. l. c., p. 211), or at least more littoral (Revision l. c., p. 15), by which the construction and structure of the shell is well explained.

The genus *Omphalia,* Zek., is at present with certainty known mostly only from cretaceous rocks: from Aptien, Cenomanien, and Gosau.

A representative, as the oldest, is known from Wealden. In the Gosau, Zekeli described nine species, which Dr. Stoliczka reduced to four, but there are to be added still three of D'Orbigny's *Turritella,* i. e., *Turritella Renauxiana, T. Requieniana,* and *Turr. Bauga,** further Coquand's species of *Cassiope* are to be placed here. Three species are described by M. Drescher (l. c.), but all distinct species are cretaceous.

Our species is very well marked and different from the others known, so that I will describe it as follows:

OMPHALIA TROTTERI, *Fstm.* Pl. I, f. 1—4.

Testa conica turrita, oblonga, umbilicata apicem versus attenuata, hoc modo lateribus paulo incurvata; anfractibus septem et pluribus; omnibus duas tantum costas distinctissimas continentibus, ultimo in solum tertia costa apparente; costis anfractorum et spatiis inter eos differenter (undulatim) striatis; apertura oblonge rotunda, columella glabra.

Measurements of the specimens.

a.—Specimen fig. 1:

Spiral angle, apical portion	46°
apertural portion	30°
Sutural angle	108°
Total height...	46 mm.
Height of the last whorl	16 mm.
Height of last whorl to total of shell (taken 100)	$\frac{35}{100}$
Breadth (below)	26 mm.

* In his Cretac. Gasteropoda of S. India Dr. Stoliczka considers this species again as *Turritella.*

b.—Specimen fig. 2:

Spiral angle apical portion	46°
apertural portion	26°
Sutural angle	106°
Total height	62 mm.
Height of the last whorl	23 mm.
Height of last whorl to total length	$\frac{37}{100}$
Breadth	31 mm.

c.—Specimen fig. 3, (fragment.)

Spiral angle, apertural portion	17°
Sutural angle	100°
Height of fragment	44 mm.
Height of specimen restored	95
Height of last whorl	21 mm.
Proportion of last whorl and total height	$\frac{22}{100}$
Breadth	35 mm.

d.—Specimen fig. 4:

Spiral angle	34°
Sutural angle	104°
Height of fragment	47 mm.
Height of shell restored	57 mm.
Heigth of last whorl	16 mm.
Proportion of height of last whorl and total of shell	$\frac{28}{100}$
Breadth	25 mm.

Description:—The shell is conical turreted, oblong, umbilicated; it is not quite regular in the whole height, but it becomes more attenuated towards the apex, so that in the upper part it is a little incurved; there are seven or more whorls bearing the chief character of the shell, two very distinct ribs, thickest in the lowest whorl and becoming thinner towards the apex. Only in the lowest whorl a third rib appears.

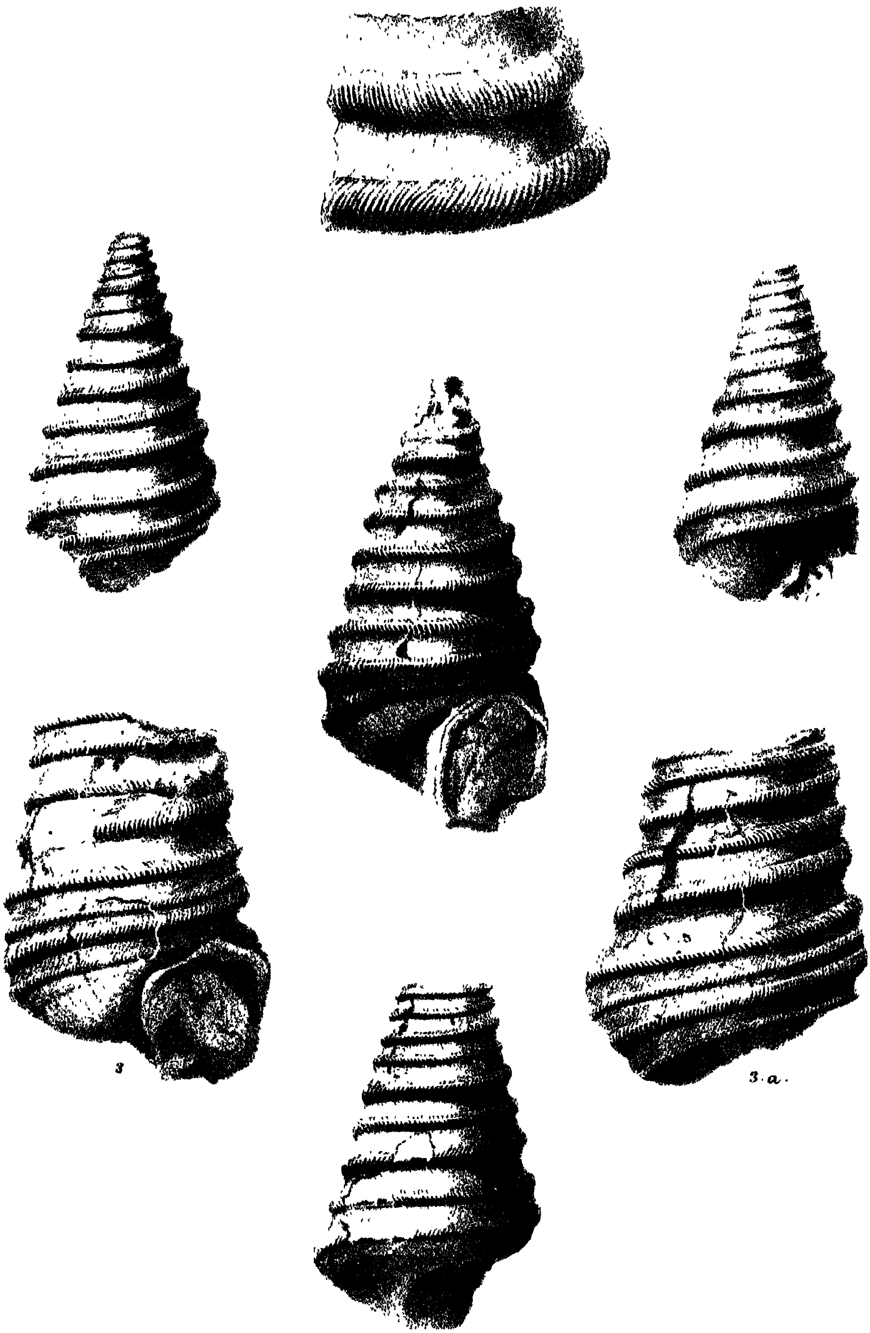
The ribs and spaces between are characteristically marked by the striation of growth, which is perfectly sinuated, and in such a manner that the lower rib, with which the whorl begins, and the next space are striated in a contrary way to that of the next rib and the following space, and so on to the apex; from this we can conclude that the emargination of the aperture was between the first and second ribs.

The aperture is oblongly round.

When we consider the measurements of the specimens, we find a spiral angle at the apical portion of 34°—46°, at the apertural of 17°—30°; the sutural angle 100°—108°; the height of specimens from 46—95 mm., height of last whorl from 16—23 mm., and the proportions of these to the total length from $\frac{22}{100}$—$\frac{37}{100}$; the breadth (below) from 25—35 mm.

These measurements enable us to compare our specimens with forms already described, but to distinguish them also.

From the measurements it follows that our species has much shorter whorls than all those described by Zekeli, the proportion of the last whorl to the total height being much smaller.



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3.a.

Feistmantel delt.
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Also those specimens figured in D'Orbigny and Coquand, and those recently described by M. Drescher (l. c.) have higher whorls.

In the other dimensions our species agrees mostly with *Omphalia Kefersteini*, Munst. spec., to which also *Omphalia suffarcinata*, Munst. spec., is to be placed.

With these our species is also otherwise related; but different by the two very well marked spiral ribs in each of the whorls, of which one runs on the lower part of the whorl, and the other in the middle of it, while in *Omphalia Kefersteini*, Munst. sp., still a third rib runs on the upper part of the whorls.

I named the species after Captain Trotter, who has presented the specimens to our museum.

As *Omphalia* as yet is known almost only from cretaceous, and mostly from upper cretaceous, we have to consider our form also as most probably of upper cretaceous age.

Cretaceous rocks in the Himalayas are known with certainty still only from Spiti, described by Dr. Stoliczka as the Chikkim limestone in his paper on North-West Himalaya in Mem. Geolog. Surv. India, Vol. V, p. 116. But only several fragments of *Rudistes* and numerous *Foraminifera* were observed.

From these fossils we had certainly to look upon the Chikkim limestone as a marine formation, while the beds near Namcho Lake with *Omphalia* were littoral or brackish.

Some rocks of cretaceous age occur in the Kasia hills, near, but quite detached from, the eastern Himalaya.

NATICA species.

From about the same locality are three other specimens of *Gasteropoda;* from the general form one can judge with much probability that they belong to the genus *Natica*, they are however imperfect just at the aperture, and none of them shows this portion sufficiently. The specimens are of a large size and all more or less compressed, as are also several of the specimens of *Omphalia*.

We know *Natica* occurs in most of the formations, and it is therefore most probable that the specimens under discussion are out of the same beds as *Omphalia Trotteri*, Fstm., *i. e.*, from *upper cretaceous* rocks.

Explanation of Plate.

Figs. 1, 1*a*, 1*b*.—*Omphalia Trotteri*, Fstm. Specimen with unknown locality, amongst the collections of the Asiatic Society of Bengal.

Figs. 2—4.—The same species. Specimens sent by Captain Trotter, and collected near Namcho Lake, Tibet.

NOTE on ESTHERIA in the GONDWANA formation, by OTTOKAR FEISTMANTEL, M.D., Geological Survey of India.

Recently, a very interesting paper was sent to me by Prof. Geinitz (Dresden) on some fossil plants and animals from the Argentine Provinces—La Rioja, San Juan, and Mendoza.* From the total of the fossils described by Prof. Geinitz, he declares the series to be of Rhætic age. This paper has induced me to examine again our *Estheria*-bearing rocks, and to compare them together regarding their homotaxical position.

1.—*Estheria in the Mángli beds.*

In the American Rhætic beds, M. Geinitz recognized, as very abundant and characteristic, an *Estheria*, which was first described by Mr. Rupert Jones† from Mángali (Mángli), Central India, between Nágpúr and Chánda, about 60 miles S.-S.-E. from the former place.

The argillaceous sandstones at Mángli contain very few other fossils, except that *Estheria* and another of much smaller form, which is as frequent as the *E. Mangalensis*, but remained undetermined. Thus, the position of these Mángli beds has remained always somewhat uncertain, although Mr. Jones thought there were reasons to consider the beds as Rhætic, which is most probably the case.

From the common occurrence of this smaller form of *Estheria* in the Mángli beds and in the Panchet group, Mr. W. T. Blanford first considered the Mángli beds as belonging to the Panchet group;‡ but in his later paper on the "Geology of Nágpúr,"§ he set aside this evidence as insufficient, and finding no stratigraphical feature whereby to separate them, he left these beds in the Kamthi group, which, without any doubt, is analogous with the Raniganj group, forming the upper part of the Dumuda series, both having the same *Phyllotheca indica*, Bunb. (the real leaved branchlets), *Vertebraria indica*, Bunb., *Glossopteris communis*, Fohn., *etc.* In a recent detailed survey of the Wardha coal-field, by Mr. Hughes,|| the Mángli beds are still left in the Kamthi group, there being no physical grounds for a separation. This should only encourage us to seek help from palæontology.

Considering that the Damuda series, in general, contains very frequently plant fossils and is especially characterized by the occurrence of *Glossopteris*, which is till now the only character of it, as *Schizoneura*, with the same species, is also numerous in the Panchet group, and that not a trace of these fossils is found at Mángli; on the other hand, that the Mángli beds contain mostly only that mentioned *Estheria*, which, with exception of Kawarsa, of which I speak further on, is nowhere found in the Damuda series, but only in younger strata, it will be perhaps advisable to look for another place for these Mángli beds; it seems to me that they are to be taken at least of the age of the Panchet group, or even still younger.

First, the plant fossils. These are very poor, and consist till now only of some stems, which have no relation with any of the Damuda fossils, but with younger forms:

a. Palissya. A stem fragment figured in Sir Ch. Bunbury's Nágpúr flora,¶ Pl. XII, f. 1, as "*Knorria?* (Portion of stem of a *Conifer?*)" is certainly a coniferous plant, as is well seen from the relation of the scars. I have an original specimen of the same, and I am convinced that it belongs to the fossil *Palissya* and most probably *Pal. Brauni.*, Endl.

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* Beitrag zur Geologie und Palæontologie der Argentinischen Republik.

I Palæontologischer Theil. II. Abtheilung: Uber Rhätische Pflanzen und Thierreste in den Argentinischen Provinzen—La Rioja., San Juan, und Mendoza. Von Dr. Hanns Bruno Geinitz. Cassel 1876.

† Jones' Monograph of the fossil Estheriæ, Palæontogr. Soc., 1862, p. 78.

‡ Mem., G. S., Vol. III., p. 134.

§ Ibidem IX, p. 32 (3 ib.)

|| Ibidem XIII.

¶ Quart. Journ. G. S., London, XVII.

b. "*Truncus filicis.*" Another stem is figured in Sir Ch. Bunbury's paper (l. c.) Pl. XII, 2, and marked "*Stigmaria ?* (Portion of the Rhizome of a fern.)"

This Mángli stem is certainly a fern stem, and is very similar to those M. Schenk described as "*Trunci filicum*" from the Rhætic beds in Bavaria. I have an original specimen in our collection from Veitlahm in Bavaria, which is almost identical with that figured from Mángli in Sir Ch. Bunbury's paper.

Besides these two mentioned forms, there are only some indistinct stems known.

Instead of an abundant flora, we find as very numerous the shells of little crustacean animals; there are certainly two forms, a larger and a smaller one.

a. Estheria Mangaliensis, Jones.—(See: Jones—Palæontograf. Soc., 1862. Monograph of fossil Estheriæ—p. 78, Pl. II, f. 16-23, and Geinitz l. c. Uber Rhätische Pflanzen und There etc.,—Pl. I, f. 1-6, p. 3). This is the larger form, which Mr. Jones described first from Mángli; we have numerous pieces of rock from there, on which this form lies abundantly. On some specimens *E. Mangaliensis* is only represented, while on some others it is mixed with the other smaller form, and still, on some others, this later only is predominant.

Jones gave several figures, which all indicate the larger form *E. Mangaliensis* J. As to the age, Mr. Jones considered these beds, for certain reasons, as Rhætic and now Prof. Geinitz describes the same species from beds of the same age in South America.

b. Estheria comp. minuta var *Brodieana*, Jones. This form was not described; it is, however, as frequent as the larger one. From the size and form, and from the structure of the shell, they can safely be taken as very closely allied to *Estheria minuta* var. *Brodieana*, Jones),* which, as Mr. Jones indicated so distinctly and exhaustively, is characteristic of the Rhætic beds.

This smaller form the Mángli beds have in common with the Panchet group, and to judge only from the *Estheria*, an animal f ossil, we may consider both on the same horizon, to which view, in the case of Mángli beds, there is no objection; but as also no plant of the Panchet group is found in the Mángli beds, the former being closer connected with the Damudas by the *Schizoneura*, while in the Mángli beds the plant-remains are very poor, and most naturally referable to Rhætic fossils, I consider, as most probable, that the Mángli beds cannot belong to the Damuda series at all, and that they are rather to be considered as the uppermost continuation of the Panchet group.

Already Mr. Hislop himself has pronounced, 1864, quite distinctly that the *Mángli beds* are to be placed above the plant-bearing beds at Nágpúr (Q. J. G. Soc., 1864, pp. 117 and 282.

The Mángli beds have yielded also a Labyrinthodont Reptile, which is described by Owen as *Brachyops laticeps*, Ow. (Q. J. G. S., 1855, p. 37, Pl. II). But this is, of course, no objection to the view I suggest, as it is well known that Labyrinthodont Reptilia occur also in the Keuper of Europe.

2.—*Estheria in the Panchet group.*

In the Panchet group, besides pretty numerous plant fossils, an *Estheria* also occurs, which is certainly identical with the smaller form of *Estheria* in the Mángli beds, mentioned as *Esth. minuta* var. *Brodieana*, Jon. I compared specimens from both localities, and I could not find any difference.

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* Jones, l. c., Pl. II.

Amongst the other fossils two ferns especially prevail, *i. e.*, *Pecopteris concinna*, Presl. and *Cyclopt. pachyrrhachis*, Göpp., which are Rhætic forms; so that one might take the Panchet group of this age—only the occurrence of the *Schizoneura Gondwanensis*, Feistm. identical with the same in the Raniganj (Kamthi) group of the Damuda series, induced me to consider the Panchet group a little older, as representative of the upper Triassic (Keuper) strata in Europe.

The reptilian remains in this group, besides the plant-remains, are also pretty frequent; and are not at all opposed to the evidence from the plant-remains; they belong mostly to the *Dicynodont* reptiles, which first were known from South Africa, where, however, their age up to the present day remains undecided.

Here, in India, however, where we know that the Panchet group overlies immediately the Raniganj group, which itself is lower Triassic, and underlies the Rajmehal group, which is, to say the least, Liassic, and where, besides the reptiles, a flora occurs, which agrees with a flora from defined strata, there can, I think, be little doubt about the homotaxical position.

In the Panchet group, therefore, the flora is additional evidence as to the age of this group, and the Panchet *Estheria* is identical with the small form in the Mángli beds. It was therefore more natural when Mr. Blanford* first took the Mángli beds as belonging to the Panchet group. I must, however, state again that no other fossil of this group, except the small form of *Estheria*, is found in the Mángli beds; and judging from the absence of *Schizoneura*, which only induced me to class the Panchets as Keuper, my conjecture, that the Mángli beds are the top of the Panchet group, is perhaps not unnatural. There are, at least as far as I know the relations, no contradictory indications.

3.—*Estheria from Kawarsa.*

The Kawarsa beds also are in the Wardha basin, and have been mapped, like the Mángli beds, with the Kamthi group. The Màngli beds occur at the top of the section, at the northern edge of the area, immediately under the Deccan trap. Mr. Hughes estimates the whole thickness to the base of the Kamthis as 700 feet. This is an extraordinarily small thickness for the period this series is supposed to represent, and considering that in a neighbouring region, below the Kota-Maléri beds, on the Godavari, there is an apparent accumulated thickness of 17,000 feet of these 'Kamthi' strata, it is certainly not too soon to endeavour to indicate horizons in such a mass of deposits. The Kawarsa beds occur near the southern margin of the basin, and Mr. Hughes speaks of them as several hundred feet from the the base of the series. They have yielded some broken plant-remains and *Estheria.*

a.—An *Equisetaceous* stalk, pretty distinct; it belongs to that group of forms which generally are termed *Phyllotheca,* which, however, as I have already mentioned, belong to a great extent also to *Schizoneura,* Schimp., and the more so, as *Phyllotheca* in the real sense is not so frequent as *Schizoneura*, Schimp.

b.—A fragment of an oblongly lanceolate leaflet with marked ribs, which might belong to *Schizoneura,* Schimp.

c.—Some broken specimens of *Glossopteris* occur very rarely in comparison with these so richly represented leaves at Nágpúr and elsewhere in the Damudas; and I have no doubt that these beds, near Kawarsa, are younger than all the real Damudas, including the Kamthi-Raniganj group.

* Mem., Geol. Sur., III, p. 134.

To this indication now is to be added the occurrence of *Estheria*, which is certainly identical with that in the Panchet group, the state of preservation and the size and form being identical; and is therefore to be considered as very likely *Estheria minuta* var. *Brodieana* Jon.

From this occurrence of the *Estheria*, an animal fossil which is still so frequent in the Mángli beds and in the Panchet group, and from the scarcity of plants altogether, and from the state of the rock, it would, I think, follow that the locality at Kawarsa is scarcely to be considered as representative of any group of the real Damuda beds, the fossils of which are everywhere so different from those both of the Mángli and the Kawarsa beds.

It must thus be admitted that this blending of the fossil forms indicates transition, and affords some support to the continuity of the stratigraphical characters in this area, whereby the whole has been mapped and published as a single rock-group; an abridged representation of the top of the lower Gondwarra series, in which the Panchet and upper Damuda groups are very closely connected.

The possible persistence of two *Estheria* horizons (as is known to occur in Europe) may, however, be worth suggesting—an upper, with two *Estheria* (Mángli), and a lower, with the *Estheria minuta* (Panchet and Kawarsa).

4.—*Estheria in the Kota beds.*

From the Kota beds on the Pranhíta, near Sironcha, Mr. Jones described also a species of Estheria as *Estheria Kotaensis*, Jones.*

The Kota locality and the neighbouring one of Maléri (Maledi) have long been famous in Indian geology for fish and crocodilian remains. The general relations of these deposits have recently been approximately fixed by the Survey. They rest upon the Kamthi beds, with more or less of unconformity, at the south end of the Wardha coal-field; extend thence down the valley of the Pranhíta to Sironcha, on the Godavari, where they again overlie an immense thickness of rocks of Kamthi aspect. But for the prevalence of red and green clays, and the frequent occurrence of a limestone, they are not themselves strikingly different in mineral character from the Kamthi type; which again, as has been often remarked, has many resemblances to that of the original Panchet group of Bengal. On this account, and from the decidedly Keuperic affinities of the majority of the vertebrate fossils of Maléri, the beds here have been hitherto regarded by the Survey as probably on the Panchet horizon; the Kota limestone, from its fish-remains, being taken as Liassic and thus presumably younger. Mr. Hughes has shown that the beds of both localities are on the same horizon, and the formation is now known as the Kota-Maléri group.†

Amongst the numerous additions to our collections of vertebrate fossils from these beds, made by Messrs. King and Hughes, there were a very few plant-remains, of which I have determined two from Maléri as common species of the Kach-Jabalpur horizon, and one, from a bed underlying the Kota limestone, as a familiar species of the Rajmahal group. It may not be established that the circumstances of position indicate a permanent distinction of these two groups in this region, as I have already shown that in their typical areas they have some forms in common. But at all events, these plant fossils go far to establish the position of the Kota-Maléri beds in our Indian series,—that they are not Panchet, but Upper Gondwana, on or above the horizon of the Rajmahal group.

This connection of the Rajmahal group with the Kota-Maléri beds is significant, so far as the strongly Rhætic affinities of the vertebrate fossils confirm my determination

* Monograf of Esther, l. c., p. 81, Pl. II, f. 24-25.

† See Hughes, Mem., Geol. Survey. Vol. XIII. p. 81.

of the Rajmahal flora as at least lower Liassic. The *Estheria* may perhaps be taken as an indication in the same direction. This *Estheria Kotaensis* may now also be taken as an Upper Gondwana form.

As the *Estheria* has hithero been neglected in India in the discrimination of horizons' I would add some illustrations of the service it has rendered elsewhere.

Estheria minuta, Jones, is a splendidly guiding fossil of the whole *Keuperic* strata in Europe. A variety of this species—*Esth. minuta,* var. *Brodieana,* J.—is characteristic of the Rhætic strata. The well-known Prof. Römer, only with the assistance of *Estheria minuta,* var. *Brodieana,* Jon., decided that certain rocks in Upper Silesia belong to the Rhætic group. He says in his valuable work, "Geologie von Oberschles," on p. 175, discussing the fossils of certain series, which he calls "Hellwalder Estherien Schichten," as follows (I give the translation):—"Except *Estheria minuta,* Jones, no organisms were observed in that series. But also by itself the little crustacean is of great importance for the determination of the age of this formation. *Estheria minuta,* J., is a very common fossil in the Keuper. A variety, *Esth. minuta,* var. *Brodieana,* J., which is marked by a smaller size and a finer reticulation in the sculpture of the shell, is according to Jones' explanation characteristic of the Rhætic strata. The Upper-Silesian form agrees very well with the figures of this variety." And from this and from some other characteristics, Prof. Römer draws the correct conclusion that those beds in Upper Silesia alluded to are of Rhætic age.

Our *Estheria* of the smaller size does not differ much from that Silesian one. Thus, two species are characteristic of certain series; and there are more of them.

Now Prof. Geinitz describes *Estheria Mangaliensis,* Jones, again from Rhætic strata, in South America. Prof. Rupert Jones has certainly not in vain devoted a monograph to the fossil *Estheria.*

NOTICES OF NEW AND OTHER VERTEBRATA FROM INDIAN TERTIARY AND SECONDARY ROCKS, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

The present paper contains short notices of several species of Vertebrata from the Tertiaries and Secondaries of India, which are either new to science, or of which some new point in the osteology or distribution is now for the first time noticed; the new species will be subsequently figured and described in the "Palæontologia Indica," although some of these descriptions will not appear for a considerable period.

BOS ACUTIFRONS, n. sp., nobis.

This species is founded upon a cranium from the Siwaliks; it may be defined from the characters of the cranium as follows:—

Frontals convex, longer than broad, horn-cores placed immediately above occiput, compressed, convex superiorly, extending at first upwards and outwards, with a slightly inward curve at their tips; centrè of forehead more prominent than bases of horn-cores; span of horn-cores when complete nearly nine feet; occipital crest narrow, rounded, and extending upwards almost to the intercornual ridge.

BOS PLANIFRONS, n. sp.

This species also is known by a single cranium from the Siwaliks, of smaller size than the last; it may be defined as follows:—

Frontals nearly flat, longer than broad, horn-cores placed above occiput, slightly compressed, convex superiorly directed outwards, slightly upwards, and at the tips inwards;

centre of forehead not in advance of bases of horn-cores; the latter shorter than in last species; occipital crest broad and narrowed, and separated by a considerable interval from the intercornual ridge.

BUBALUS PLATYCEROS, n. sp., nobis.

Frontals nearly flat, rounded superiorly, horn-cores triangular, placed in advance of the plane of the occiput, superior border concave, directed upwards and outwards, tapering rapidly, widely separated at their bases; exterior face continuous with the plane of the frontals; occipital crest broad and rounded, entirely distinct from the intercornual ridge This species is also from the Siwaliks.

STEGODON GANESA, F. & C.

A tusk of this species from Biltari in the Nerbudda valley has been for a long period in the Indian Museum, though the species has never been described from the Nerbudda deposits; it comprehends the greater portion of the middle part, and is from the left side; it is characterized by being laterally compressed, and by the extremity curving upwards and inwards; in the above points, and in its size, it exactly corresponds with the tusk of Colonel Baker's cranium of *S. ganesa*. The dimensions are as follows:—

	Feet.	Inches.
Length of fragment along concave upper border	6	7
Length of chord of arc	6	1
Vertical diameter near proximal extremity	0	8·5
Transverse ditto ditto	0	7·3
Vertical diameter at distant extremity	0	6·7
Transverse ditto ditto	0	4·7

The base of the tusk is absent, and must have been of considerably larger diameter than our fragment, perhaps as large as that of the tusk of Colonel Baker's specimen of this species, which has a vertical diameter of nearly ten inches. The tusks of *S. insignis* are never more than three or four inches in diameter, while those *Elephas namadicus* are usually of about that size, but are occasionally larger. The largest known cranium of the latter species is in the Indian Museum; it is described by Dr. Falconer in the Catalogue of the Asiatic Society's Collection, p. 235. The largest diameter of the incisive sheath of that specimen is 6·6 inches; this being the transverse diameter, the vertical diameter is somewhat smaller. The shape of the incisive sheath, as well as its small size, shews that the tusk in question could not have belonged to *Elephas namadicus*, since the above-mentioned cranium, of the latter species, in the Indian Museum, belonged to an unusually large individual. The cranium to which the tusk under discussion belonged must have had an incisive alveolus, of which the vertical diameter was at least nine and a half inches. The exact agreement, both in form and size, of our specimen with the left tusk of Colonel Baker's gigantic cranium of *Stegodon ganesa*, now in the British Museum, is of itself amply sufficient to prove that our Nerbudda specimen belonged to that species. We have no complete tusks of *Elephas namadicus* in the Indian Museum, but such fragments as we possess indicate that these tusks were nearly straight and cylindrical, and therefore quite unlike the present specimen. The large size of our specimen sufficiently distinguishes it from *Stegodon insignis*.

The range in time of *Stegodon ganesa* must now be made equivalent to that of the allied *Stegodon insignis*, which lived down to the Nerbudda period, and must have been a contemporary of the early human inhabitants of India.

SIVALHIPPUS THEOBALDI, n. gen., nobis.

This genus is formed upon the evidence of a portion of the left maxilla with teeth of an aberrant horse lately sent down by Mr. Theobald from the Siwaliks of Keypar in the

Punjab. The specimen contains the four anterior teeth of the molar series, which have only just come into wear; only a short notice is here given of these teeth, as they will subsequently be figured and fully described.

The first premolar is very small; it is inserted by a single fang; the three succeeding teeth are inserted by distinct fangs, and their crowns are consequently extremely short; their grinding surfaces are oblong, their antero-posterior diameter being the longer of the two; the second tooth is elongated. The larger teeth consist of six lobes, of which the outer and middle pairs are the larger, the latter pair being concave externally; the antero-internal lobe is placed between the two median lobes, and is entirely unconnected with them; the postero-internal lobe is connected by a narrow bridge with the postero-median lobe; the medial enamel infolds are deeply crenulated, and all the hollows are filled with cement; the length of the three large teeth is 3·05 inches; the length of the penultimate tooth is 1·25 inches, and its breadth 0·9 inch.

The teeth approach nearest to those of *Hippotherium*, but are distinguished among other characters by their elongated crowns, and by being inserted by distinct fangs as soon as they are protruded; in the latter character they agree with the American *Protohippus* and *Merychippus*, but are distinguished by having the antero-internal column detached from the antero-median column.

The completeness of the median columns distinguishes these teeth from those of *Anchitherium* and its kindred.

The generic name is derived from the name of the beds in which the specimen was found, and the specific name is given after Mr. Theobald, the discoverer of this and so many other Siwalik fossils.

An examination of the remains of Siwalik *Equidæ* in the Indian Museum has convinced me that, besides the above new genus, there are two species of true *Equus* from these deposits,—namely, *E. sivalensis*, and a new species; and that there are also two species of *Hippotherium*,—namely, *H. antilopinum*, and a larger new species. Two detached middle molars of the latter species are figured by H. von Meyer in the fifteenth volume of the German Palæontographica, under the name of *Equus primigenius* (=*Hippotherium gracile*); a more complete series of the dentition of this species enables me to state that it is certainly distinct from the European species, which must consequently be expunged from the lists of Indian fossils. A memoir on the dentition of all the Indian fossil *Equidæ*, in which the new species will receive names, will subsequently appear.

ICTITHERIUM SIVALENSE, n. sp., nobis.

The above genus of Viverroid carnivores was first made known to science by M. Gaudry, who determined two species from the upper miocene of Attica; two fragments of the mandible of a Viverroid carnivore, lately sent down by Mr. Theobald from the Siwaliks of the Panjab, appear to agree very closely with the lower jaw of the European *I. robustum*, and I have accordingly referred them to that genus with the specific name of *sivalense*.

The two fragments are respectively from the right and left sides, and probably belonged to the same individual; the larger of the two comprehends the hinder half of the left ramus, lacking the condyle and the coronoid and angular processes; it shews the sectorial molar, the socket of the second molar, and the greater part of the ultimate premolar; the smaller fragment comprises a portion of the middle of the right ramus shewing the two last premolars.

The jaw is arcuated on the inferior border, and is of great depth; the sectorial molar has two outer lobes,—an accessory lobe on the inner side of the second of these lobes, and a talon; the premolars have the same general form as in *Ictitherium;* the crown of the last molar is not shewn. The length of the sectorial molar is 0·7 inch, of the last premolar 0·57; the depth of the jaw is 0·97 inch; the specific differences between this species and *I. robustum* will be subsequently pointed out.

The lower jaw of this genus is distinguished from that of *Hyæna* by the presence of two molars; from *Gulo* and *Putorius* by the presence of the inner lobe on the sectorial; the dental formula of *Ictitherium* is the same as in *Martes* and *Vivena*, but the jaws of the two latter genera are much more slender, and the form of the teeth is also somewhat different.

DINOTHERIUM AND ANTOLETHERIUM.

Among a collection of specimens lately received in the Indian Museum from the Asiatic Society, the original lower jaw, from a drawing of which Dr. Falconer founded the genus *Antoletherium*, has been discovered. Dr. Falconer's notes on the drawing will be found in the "Palæontological Memoirs" (vol. I, p. 416), where a copy of Colonel Baker's drawing is also given (Pl. 34). This drawing, however, is incorrect; the centre tooth (B) should have three in place of two transverse ridges, while the tooth on the right (C) should have but one ridge. From a note on page 417 of the Palæontological Memoirs it seems that Dr. Falconer subsequently received a correct sketch.

In the same collection, I have also found a portion of a lower jaw with two slightly worn molars from the Siwaliks, which undoubtedly belongs to *Dinotherium*, but which is remarkable for having an incomplete longitudinal ridge between the transverse ridges of the molars, which when worn down would resemble the pattern of the molars of the so-called *Antoletherium;* a smaller and less complete ridge is found in the lower molars of *Dinotherium giganteum.* No other animal but *Dinotherium* has a single three-ridged tooth between two-ridged teeth, as occurs in the so-called *Antoletherium.*

I think that there can be no doubt but that the lower jaw, to which the name of *Antoletherium* has been applied, really belongs to *Dinotherium*, and that the former name must be abolished. The central tooth (1st molar) of the Attock jaw agrees precisely in size with the first upper molar of a *Dinotherium* from the same locality noticed by Falconer, on page 414 of the first volume of the "Palæontological Memoirs," and which I have figured as *D. pentapotamiæ* in a forthcoming number of the "Palæontologia Indica:" the two doubtless belong to the same species. The jaw in question affords additional proof of the specific distinctness of the Punjab *Dinotherium;* both of the re-discovered specimens will be subsequently figured in the "Palæontologia Indica."

HYÆNARCTOS SIVALENSIS, Falc. and Cant.

Mr. Theobald has lately sent down a nearly perfect mandible of this species, which is exceedingly important, as it shews that, from the incompleteness of his specimen, Professor Owen was led astray in assigning the teeth to their proper position in the series. The new specimen shews the three true molars, and the sockets of the premolars; the last molar has a circular crown, and is not shewn in the specimen figured by Professor Owen in his Odontography (Pl. 131). From the absence of this tooth, Professor Owen considered the second molar as the last of the series, the carnassial as the second molar, and the last premolar as the carnassial (*Odontography*, p. 504). The new specimen shews that the carnassial is much larger than any of the other teeth, and that the form of the last molar agrees more nearly with the same tooth in the true Bears than was the case according to Professor Owen's interpretation of the homologies of the teeth. A figure of the new specimen will appear in the "Palæontologia Indica."

MERYCOPOTAMUS DISSIMILIS, Falc. and Cant.

Since publishing my notes on the Osteology of this genus, in the last volume of the "Records" (p. 144), I have had an opportunity of comparing the axis vertebra and the astragalus of *Merycopotamus* with the corresponding bones of *Hyopotamus bovinus* from the upper eocene of Bracklesham, and find that these bones of the two genera are so close in form as to be almost undistinguishable one from the other, and were it not for the evidence of the skull and teeth, they would at once be referred to the same genus. I give here the dimensions of the axis and astragalus of *Hyopotamus*, which may be compared with those of the same bones of *Merycopotamus* given on pages 151 and 152 of the last volume of the "Records":—

Axis Vertebra.

	Inches.
Length of centrum	2·9
Width of posterior surface of ditto	1·2
Depth of ditto	9·5
Width across anterior articular facet	2·6
Length of odontoid process	6·8
Width of ditto	6·9

Astragalus.

Extreme length	2·3
Width across tibial trochlea	1·1
Ditto distal extremity	1·3
Width of cuboidal articular facet	0·64
Ditto navicular ditto	0·66
Length of calcaneal trochlea	1·3
Width of ditto	0·7

I have not had an opportunity of comparing any other of the limb bones of *Hyopotamus* with those of *Merycopotamus*, but the figures of the bones of the foot of the former genus seem to be very like the corresponding bones of *Merycopotamus.*

The above resemblances serve to shew that *Merycopotamus* must be a survivor of a very ancient type of structure; and also shew that the genus has affinities on the one hand as shewn by teeth and limb bones with the *Hyopotamidæ*, and on the other, as shewn by its skull and lower jaw, with the *Hippopotamidæ.*

PARASUCHIAN CROCODILE.

Mr. Hughes has lately sent in a specimen of a scute of a Crocodilian from the Dénwa group of the Mahadeva series, collected by him on the banks of the Dénwa river. The specimen is of importance, as hitherto no fossils have been obtained from these beds. I hope on a subsequent occasion to give a figure of this scute, and therefore at present shall only roughly describe it. The specimen is of large size, being at the centre more than an inch in thickness; it seems to have belonged to the dorsal series of scutes, and is from the right side; it is fractured through its centre, the longitudinal ridge being broken away; externally, it is convex from side to side; the inner border presents a flat surface for sutural union with its fellow of the opposite side; the posterior border is bevelled away inferiorly and overlapped the anterior border of the succeeding scute; a great part of the anterior moiety has been broken away. The upper surface is deeply pitted, and the peripheral pits are expanded into elongated grooves presenting a radiating arrangement. The specimen when complete was probably as large as broad, and indicated an animal of gigantic dimensions; the length of the one complete (inner) border is 6·1 inches. The above-mentioned characters shew that the specimen belonged to the Amphicœlian Crocodilia so characteristic of the

mesozoic period. (See Huxley, Q. J. G. S., Vol. XV, p. 446.) At the anterior border of the specimen there is a smooth hollow on the inferior surface, which may possibly have received the extremity of a long peg from the anterior scute. A similar arrangement occurs in the scutes of *Goniopholis crassideus* of the English Purbeck; but in that genus the peripheral pits are not elongated as in our specimen, and have consequently no radiate arrangement.

The form of the pits and the articulations of the two remaining lateral surfaces agree very closely with those of the dorsal scutes of *Belodon* from the upper Keuper and Rhætic of Würtemburg,* and the arrangement of the pitting also agrees very closely with that which covers the scutes of the allied Indian genus *Parasuchus*, from the Kota-Maléri beds. The present specimen is, however, of very much larger size than any specimens of the scutes of that genus from those beds, although we have vertebra in the Indian Museum from those same beds which belonged to an individual which might not have been very much smaller than that to which the Denwá scute belonged. I think we may safely say that the above scute belonged to the group of Crocodilia Parasuchia, and very probably to the genus *Parasuchus*, but that the species was probably distinct from the Kota-Maléri species.

We have, in the Indian Museum, from a third distinct locality, an amphicœlous vertebra of a crocodile from the Chari beds of Kach, which is considerably like those from the Kota-Maléri beds.

This vertebra has an elongated and laterally compressed centrum, somewhat expanded at the ends; the articular surfaces are vertically elliptical and hollowed; there are large transverse processes, and a well-developed neural spine; the zygapophyses are concealed by matrix. The neurocentral suture is clearly marked and is placed considerably below the transverse process, the latter consequently rising entirely from the arch; this shews that the vertebra belonged to the posterior dorsal series, the rib not articulating with the centrum. The vertebra could only belong to the *Crocodilia Amphicælia* or the *Plesiosauria;* the dorsal vertebræ of the latter order are, however, cylindrical and generally shorter than the present specimen, the proportion of the long diameter to the transverse diameter being in the Macrospondylian Plesiosauri never more than in the proportion of 10 to 8, while in the present specimen these two diameters are in the proportion of more than 2 to 1. A similar proportion prevails in the vertebræ of many of the Amphicælian crocodiles, to which group our specimen must belong. The dimensions of the specimen are—

	Inches.
Length	3·1
Breadth of centrum (transverse)	1·4
Height of centrum	1·65

The specimen has already been referred to by Dr. Feistmantel† as belonging to the genus *Parasuchus*. I am not, however, quite sure whether this is the case, but I think it is almost certain that the vertebra in question belonged to the *Crocodilia Parasuchia* and quite possibly to *Parasuchus;* it will require the discovery of scutes in the Chari beds to be quite sure as to the generic position of the vertebra.

If the specimen belongs to *Parasuchus*, it tends somewhat to approximate the horizons of the Chari and Kota-Maléri beds; the former beds have been considered as the equivalents of the Oxfordian and Callovian of Europe; but Dr. Feistmantel has indicated the existence of Liassic forms in these beds, which tend to place them on a somewhat lower horizon than the

* *Von Meyer Palæontographica*, Vol. VII, Pl. 43.

† Rec. Geol. Surv., India. Vol. IX, p. 16.

Oxfordian. In any case, however, the Chari beds must be considered newer than the Trias and the Rhætic, and the occurrence of a (probably) Parasuchian Crocodile in these beds somewhat does away with the value of that group as characteristic of the Trias or Rhætic.

I may here mention that the occurrence of the remains of a fresh-water Crocodile in the marine Chari group is paralleled by the occurrence of the estuarine *Teleosauri* in the marine Lias of Whitby; its presence serves to indicate that the Chari beds were deposited in a sea not far removed from the estuary of some large river.

Having now defined the affinities of our Denwa scute, and noticed the position of other allied forms in the Indian rock-series, we may turn our attention to consider whether it affords us any assistance in fixing the homotaxis of the rocks in which it occurs, during which we shall be led also to consider the age of the Kota-Maléri beds. From the great similarity of structure between the Denwa scute and the scutes of *Parasuchus* from the Kota-Maléri group, with the scutes of the European genus *Belodon*, I am inclined to think that the horizons in which these three forms occur cannot be very far removed in time; and, therefore, that the period of deposition of the two Indian groups must be somewhere near that of the upper Trias or Rhætic of Europe in which *Belodon* occurs.

We may here consider somewhat more closely the range in time of the vertebrates of the Kota-Maléri group; firstly, we find that the group of *Crocodilia Amphicælia*, which embraces the minor division of the Parasuchia, ranges in Europe from the upper Trias to the Chalk, and is therefore characteristic of the greater part of the Mesozoic period; the smaller divisions of Parasuchia, which in Europe includes the two genera *Belodon* and *Stagonolepis* according to Professor Huxley,* is in that region confined to the Trias. Dr. Feistmantel, however, tells me that some of the beds in which *Belodon* occurs are now classed as Rhætic.

In addition to *Parasuchus*, the Kota-Maléri beds have also yielded remains of *Hyperodapedon*, which seems probably to belong to the Rhynocephala, and which in Europe is confined to the Triassic period. From the same deposits we also have three genera of fish—*Ceratodus*, *Lepidotus*, and *Æchmodus*; the first of these three is represented by the greatest number of species in the Trias of Europe, and is not known before that period; it is, however, found again in the Oolites of Stonesfield, and a solitary surviving species still lingers on in some of the rivers of Queensland. The genus *Lepidotus* in Europe ranges from the Lias to the lower Chalk, but is most common in the former period; the species described by Sir Phillip Egerton from the Kota beds of Hyderabad in the Journal of the Geological Society for 1851 is said to be most nearly allied to the oldest English forms; the genus undoubtedly belongs to a primitive type of fish; the genus *Æchmodus* in Europe is exclusively Liassic.

The following table represents the distribution of the above-mentioned genera:—

		EUROPE.					INDIA.		
		Trias.	Rhæt.	Lias.	Oolite.	Cret.	Kota.	Denwa.	Chari.
PARASUCHIA ...	Belodon ...	×	×	...	...	...	...	...	...
	Parasuchus ...	...	...	...	...	..	×	×	× ?
	Stagonolepis	×	...	...	...	...	...	...	...
RHYNOCEPHALA ...	Hyperodapedon	×	...	...	...	...	×	...	...
PISCES ...	Ceratodus ...	×	...	...	×	(living)	×	...	...
	Lepidotus ...	...	...	×	×	×	×	...	...
	Æchmodus ...	...	...	×	...	...	×	...	...

* Quar. Jour. Geol. Soc., 1875, p. 49.

The above table indicates a somewhat long period of time to which to refer the Kota-Maléri and Denwa beds; but I think we are justified in saying that they are not homotaxically older than the upper Trias or newer than the lower or middle Lias of Europe, and that they might, with a fair show of probability, be referred to the Rhætic period, or somewhere very close to that period.

The whole of the vertebrates from the Denwa and Kota-Maléri groups, as well as those from the older Panchet group, were inhabitants either of fresh water or of the land, and therefore indicate either a fluviatile or sub-äerial origin for the groups of rocks in which their remains are embedded.

The following remarks as to how the above determination agrees with the assigned position of the Denwa and Kota-Maléri beds have been kindly added by Mr. Medlicott:—

The Denwa fossil is a very timely find;—directly, as the first fossil from an immense thickness of strata; and indirectly, because, so far as it is identifiable with others from outlying localities, it supplies the all-important test of stratigraphical position, occurring as it does in the fullest continuous section of the Gondwana deposits. In this way it already furnishes a confirmation of the horizon, as very recently determined by Dr. Feistmantel, for the Kota-Maléri beds, and also for his judgment upon the relations of the Jabalpur and Rajmahal groups.

From a fair amount of evidence, Dr. Feistmantel has insisted on the close correspondence between the flora of the Umia zone (the top of the Jurassic series of Kach) and that of the Jabalpur group (the top of the Gondwana series in Central India), both having a strong Bathonien facies. The Rajmahal group he placed lower, the flora having Liassic affinities. The Kota-Maléri beds have hitherto been taken to be on the Panchet horizon, and therefore lower Gondwana. A few plant fossils were lately found in those localities; those from the bone beds were Jabalpur species; and in the underlying beds a Rajmahal plant occurred. The stratigraphical separation not being very decided, the group may be taken as representing the Rajmahal and an overlying zone. From Mr. Lydekker's estimate it would seem that the vertebrate remains are of a somewhat older type than that of the flora.

In the continuous section of the Satpura basin, the Denwa beds occupy an upper-middle position in the great thickness of the upper Gondwana strata, hitherto vaguely spoken of as the Mahadeva series,* between the Jabalpur group and the Bijori beds, which have been sufficiently identified with the Kamthi-Raniganj horizon of the lower Gondwanas in other areas. Several hundred feet of strata, known as the Bagra beds, occur between the Denwa and the Jabalpur beds; and below the Denwa group occurs the great Pachmari sandstone, the base of which has been conjectured as the probable horizon of the Panchets. In this standard section, then, the Denwa fossil confirms in a very satisfactory manner the position independently assigned from the flora for the Kota-Maléri group. If we could venture to press closely such slight evidence, we might conjecture that the Rajmahal group will have to take its equivalent out of the great Pachmari sandstone.

In his independent classification from examination in the field, Mr. Hughes places the Kota-Maléri beds low in the upper Gondwana series; well below the Balanpur coal, which very closely represents the coal in the Jabalpur group of the Satpura region.

If the fossil which Mr. Lydekker doubtfully identifies as *Parasuchian* from Kach should prove to be such, and thus a connecting link with the Kota-Maléri and Denwa horizon, we should have made an important step in extending the parallel between the marine Jurassic series of Kach and the Gondwana series; for that fossil also occurs well below the Umia-Jabalpur horizon, in the Chari on the Katrol group of Dr. Stoliczka's classification.

* Mem. Geol. Survey, Vol. X.

TITANOSAURUS INDICUS, n. gen. nobis.

I have formed the above new genus of *Dinosauria** upon the evidence of a large femur, and two large posterior caudal vertebræ, which are in the Indian Museum, and which were obtained from the Lameta group of rocks. The femur was collected by Mr. Medlicott in the year 1871 from the Lametas of Jabalpur; the vertebræ were also obtained from Jabalpur, and are shortly described in Falconer's "Palæontological Memoirs" (vol. 1, p. 418); the larger of the two is figured on a small scale in Plate 34 of the same work. No reference was, however, made to their affinities or even as to their position in the vertebral series.

I will first extract Dr. Falconer's description of these vertebræ, then compare them with the vertebræ of the other Dinosauria to which they are allied, and finally describe Mr. Medlicott's specimen of the femur. Dr. Falconer states: "The larger vertebræ consists of a compressed body, very considerably compressed sideways, and contracted in diameter between the articular surfaces, both in the vertical and transverse direction. The anterior articulation is elliptical vertically in its outline, and the cup as deep as in the *Crocodilia;* the posterior articulating surface is of a corresponding reversed form, *i. e.*, very convex, flattened laterally, the greatest convexity being towards the middle or axis. The inferior surface of the body at either end bears immediately behind the rim of the cup in front, and in front of the ball behind a pair of surfaces for the articulation of a chevron bone, *i. e.*, each chevron has been articulated to two adjoining vertebræ.

"The spinous process, which is broken off (near the summit), is flattened and of considerable size near the base; it is given off from the body backwards at an angle of about 45°. Between it and the body there is a semicircular niche about 1·2 inches deep. From the anterior part or base of the spinous process two articular apophyses are given up, nearly horizontally, or inclined upwards at a small angle; and diverge, but the divergence is small. The articular surfaces are on the axial side.

"It would appear that the next anterior vertebræ passed its spinous process between these articular surfaces; but no marks of such articulation are seen in the spinous process of the vertebræ.

Dimensions.

	Inches.
Extreme length of body	5·4
Height in middle to hollow between spinous and articulating apophyses ...	4·9
Height of anterior concave end	3·4
Width of ditto	2·4
Length of body from rim to base of ball	4·1
Height of base of ball behind	3·4
Transverse diameter of ditto	2·3
Height of body where constricted behind	2·8
Greatest constriction of ditto	1·3
Length of articular process	2·2
Ditto from base of spinous process to top of ditto	4·0
Length of lamina, right side	1·8
Vertical diameter of spinous process	1·9
Transverse diameter of ditto	0·8

"Vertebral canal small and constricted, not a trace of a suture remaining.

"The other vertebra (unfigured) is shorter and less perfect. The spinous process is broken off at the base, and the articular processes, if any, are gone. The body is shorter and less constricted; there are the same ball and socket ends, but they are not so deep; there are also the two surfaces for chevron bones."

* The term *Dinosauria* is here used in a general sense, as comprehending both the *Ornithoscelida* and the *Sauroscelida* of Professor Huxley.

To the above description I would add that there are no transverse processes; that the neural arch is anchylosed to the anterior half of the upper borders of the centrum, the posterior half of the latter being free; that a longitudinal furrow traverses the hæmal aspect of the centrum; and that the prezygapophyses are cylindriform and project far forwards.

We will now inquire to what animal the vertebræ are likely to belong. Firstly, from the presence of surfaces for the attachment of chevron bones, from the small size of the neural canal, and from the absence of posterior zygapophyses, it is quite clear that the vertebræ belong to the caudal region; and secondly, from the absence of transverse processes, and from the comparatively small size of the neural spine and prezygapophyses, it is clear that they belong to the posterior half of the caudal region.

The only mammalia of large size which have chevron bones attached to the caudal vertebræ are the *Edentata* and the *Cetacea;* in the former order all the caudal vertebræ have transverse processes, and the centrum is short and cylindrical; in the latter the centrum is still shorter and more discoidal. It is therefore clear, independent of their geological position, that the bones do not belong to the mammalia.

Turning now to the reptiles, we find that in the *Crocodilia* and the *Lacertilia* the posterior caudal vertebræ, though procœlous, have a persistent neuro-central suture; the neural arch extends as far back as the centrum; there are both pre- and post-zygapophyses; there is generally a transverse process, and the chevron bones articulate with only one vertebra;—so that each vertebra has only one pair of facets on its hinder border for their articulation. Orders of reptiles such as the *Ichthyosauria, Plesiosauria, Chelonia, Dicynodontia,* etc., have vertebræ of totally different types, and require no comparison with our specimens.

If, however, we turn to the order *Dinosauria,* we find that here we do meet with vertebræ which agree very closely with our present specimens; if we compare the figure of a posterior* caudal vertebra of *Pelorosaurus,* figured on Plate 26 of the Philosophical Transactions for 1850, with Dr. Falconer's figure of the Jabalpur vertebra (the two figures being taken from opposite sides of the bones), we shall find a very great resemblance in many points of essential structure. Firstly, both vertebræ agree in being elongated, in the absence of any transverse process, in having a neural arch of considerable height, in carrying prezygapophyses, but no post-zygapophyses; in the former, being cylindriform and projecting in front of the centrum, and in having a small neural canal; moreover, in both, the neuro-central suture is completely obliterated, while the neural arch does not extend backwards beyond the middle of the centrum, the posterior half of the latter being quite free; both vertebræ likewise have the inferior border of the centrum arched.

Having now considered the points of resemblance, we must point out the differences between our Jabalpur vertebræ and those of *Pelorosaurus.* The most striking difference is that our vertebræ are markedly concave anteriorly and convex posteriorly, whereas those of *Pelorosaurus* are slightly concave anteriorly and nearly flat posteriorly; the latter are also approximately cylindrical, and carry facets for the chevron bones only on the hinder extremity. The caudal vertebræ of Iguanodon (Owen, Brit., Cræt. Rep., Pl. 37) resemble our specimens in carrying two pairs of facets for the chevrons; they differ, however, by being thicker, nearly cylindrical, and by the greater length of the neural arch in proportion to the length of the centrum. The caudal vertebræ of *Cetiosaurus,* figured by Professor Philips in his Geology of Oxford, are very like those of *Pelorosaurus;* but the pre-zygapophyses are not cylindrical and do not project so far forward as in *Pelorosaurus.* The caudal vertebræ

* This specimen is called by Dr. Mantel " median caudal; it is, as stated in Philips' Geology of Oxford (p. 266) really a posterior caudal.

of *Hylæosaurus* also resemble our Indian specimens in having two pairs of facets for the chevron bones, and in having a longitudinal furrow on the neural aspect of the centrum; their articular surfaces are, however, nearly flat, and their centra sub-cylindrical.

The above comparisons, I think, prove quite clearly that our Jabalpur vertebræ belonged to a Dinosaur, closely allied to *Pelorosaurus* of the English Wealden, and to *Cetiosaurus* of the Bath oolite, and also presenting points of affinities to *Hylæosaurus* and *Iguanodon* of the Wealden. The Indian Dinosaur, however, differed from all the above genera in having the caudal vertebræ distinctly "procælous" and laterally compressed.* From the large size of the vertebræ, I propose for the new genus the name of *Titanosaurus* with the specific name of Indicus. The length of the posterior caudal vertebræ of *Cetiosaurus* varies from five and a half to six and a half inches, so that our Indian species must have been nearly as large as the English giant. The forms of the articular surfaces of the vertebræ are quite sufficient to distinguish the Indian genus from all other genera of Dinosaurs.

Turning now to the femur, we find that this bone is embedded in matrix, and only shews its anterior aspect; both the condyles and the head have been broken away, so that we are unable to estimate either the full length or breadth of the complete bone; our specimen is from the left side, and agrees precisely in form with the larger femur of *Cetiosaurus* figured in diagram 108 of Professor Philips' Geology of Oxford; like that specimen, the anterior surface of our specimen is nearly flat, the inner border markedly concave, with a slight swelling two-thirds up from the distal end, which represents the third trochanter, and with the outer border less concave. The length of the fragment remaining is 46 inches, the breadth taken obliquely at the upper end 13 inches, the breadth of the narrowest part 8·3 inches, and of the broken distal end 11·5 inches. The specimen must have been at least 55 inches in length when perfect; the largest femur of *Cetiosaurus* known is 64 inches in length. The femur of *Pelorosaurus* is like that of *Cetiosaurus*, but smaller; that of *Iguanodon* is distinguished by possessing a third trochanter; the femur of *Hylæosaurus* is, I believe, not known. The size of the femur, therefore, shews an animal somewhat smaller than the largest individuals of *Cetiosaurus*, which Professor Philips estimates to have attained a length of sixty or seventy feet.

Both the vertebræ and the femur having been found in the same locality, and from the same formation—both belonging to Dinosaurian reptiles of gigantic size, and both having affinities to the same group of Dinosaurs—it is a logical inference that both should be referred to the same animal; if the femur had been found alone, I should have referred it to the genus *Cetiosaurus*, but the vertebræ forbid this view.

Both *Cetiosaurus* and *Pelorosaurus* were reptiles of terrestrial habits, probably living in marshy or estuarine districts, and we may infer that Titanosaurus, probably, had much the same habits; its occurrence in the Lametas indicates that these beds, as has previously been suggested, are of fresh-water orgin, like the Wealden of England. The caudal vertebræ of Titanosaurus belong to what we are usually accustomed to consider a higher type of structure than those of any of its European kindred. We may hope at some future date to find other remains of this huge Saurian, which will throw further light on its affinities, and shew whether it differed in other essential points from its European congeners.

The Lameta group of rocks are supposed by Mr. Blanford and Mr. Medlicott to be connected with the middle cretaceous rocks of Bagh (see Rec. Geol. Survey, India, vol. V, p. 115). The occurrence in these rocks of a Saurian closely allied to *Pelorosaurus*, and

* The caudal vertebræ of *Macrorosaurus semnus* from the Chloritic marl of Cambridge, are procælous and compressed; this genus is doubtfully referred to the Dinosauria.

in some respects to *Hylæosaurus* and *Iguanodon* of the Wealden period, suggests that the Lametá group is not far removed from the lower cretaceous period—a view which would agree with their generally accepted position in the geological series.

I have lately found in the Indian Museum a considerable series of caudal vertebræ of this genus, which were collected by Mr. W. T. Blanford in the Lametas of Písdúra; they are somewhat less compressed than the described specimen: and are accompanied by coprolites, and some portions of the carapace of a Chelonian. I shall hope subsequently to give figures of the more perfect specimens. The vertebræ and femur referred to by Mr. Hislop in the twentieth volume of the Journal of the Geological Society (p. 282) probably belong to this genus.

MEGALOSAURUS, sp.

the fourth volume of the "Memoirs of the Geological Survey of India" (p. 128), Mr. H. F. Blanford announced the occurrence of the remains of this genus in the Arrialur group of Trichinopoli (Upper Cretaceous); this announcement, however, does not seem to be generally known, as Professor Phillips in his "Geology of Oxford" (p. 196), in speaking of the distribution of *Megalosaurus*, makes no mention of its occurrence in India; for this reason I have introduced the genus here.

The specimen on which Mr. Blanford's determination was made is the greater portion of a (probably) lower tooth; this tooth is laterally compressed, the anterior border is convex and the posterior concave, both produced into trenchant edges and marked by fine serrations; the transverse section is somewhat pear-shaped, the broader portion being in front. The height of the portion of the tooth remaining is 1·8 inches; the antero-posterior diameter of the base ·91 inch, and the transverse diameter ·4 inch.

The tooth in form and size is almost identical with the teeth of *Megalosaurus Bucklandi* of the Stonesfield and Portland oolites, the only difference being that the posterior border of the Indian tooth is rather straighter than that of the English species.

In England the genus *Megalosaurus* ranges from the Lias to the Wealden, and is therefore chiefly characteristic of the Jurassic period. In India, as we said, it occurs in rocks, of which the marine mollusca fauna is homotaxically equivalent to that of the upper cretaceous rocks of Europe. This instance should make us extremely cautious in correlating the horizons of Indian and European rock-groups upon the sole evidence of land animals. As in many other instances in India, the land flora or fauna (exemplified in this case by *Megalosaurus*) of a group of rocks, indicates a lower homotaxis for the group than does the marine fauna. This anomaly is probably to be explained by the greater similarity of physical conditions, and the consequent greater facility for migration in the ocean than on the land (to say nothing of the insulation of parts of the latter), by which the organised products of the former would sooner arrive at a new station than those of the latter; the assumption in this case being that the wave of migration has travelled eastwards.

Further remains of the Indian form are required to establish its specific distinctness; the tooth will subsequently be figured.

PLESIOSAURUS INDICUS, n. sp. nobis.

I have already recorded* the occurrence of a species of the above genus from the Umia beds of Kach. On further examination, I now find that the specimen of the symphysis of a mandible, on the evidence of which the announcement was made, differs both in size and in the direction of the alveoli of the teeth from the mandible of *Plesiosaurus dilichodeirus* from the English Lias; it also differs, as far as I can make the com-

* Rec. Geol. Surv., India, Vol. IX, p. 154.

parison, from other described species of the genus; all the cretaceous and most of the oölitic species of English *Plesiosaurus*, however, are described from teeth or vertebræ only,* so that there is a possiblity of our species being identical with one or other of these forms. I have, however, thought it best to give the Indian form a distinct name, if only to mark the locality from which it was obtained, and I propose to call the species *P. indicus;* no more accurate definition, however, can be given than that published in the first notice. A species—*P. Australis*—has been described by Professor Owen from Australia, so that we now know that the genus had wide distribution in space as well as in time.

PACHYGONIA INCURVA.—*Huxley.*

This species of Labyrinthodont was described by Professor Huxley(†) from the Panchet group of rocks upon the evidence of a portion of a mandible wanting the extremity of the dentary piece; the jaw is characterized by carrying a row of minute teeth, which in cross section are transversely elongated. Among some specimens more recently acquired from the same group of rocks, I have found a part of a symphysial end of a left ramus of the mandible and a detached tooth of a Labyrinthodont, which belong to this genus. The mandible carries on its outer border a row of small, transversely, elongated teeth, from the form of which, and from the resemblance of the sculpture on the outer surface of the jaw to the same part in the type-specimen, I have referred the new specimen to *Pachygonia.* At the anterior extremity of the specimen, and placed somewhat internally to the outer row of teeth, there is one large conical tooth, longitudinally striated, and bearing the same relation and proportion to the outer row of teeth as does the similarly situated tooth in the jaw of *Labyrinthodon pachygnathus*, figured by Professor Owen in his Odontography (Pl. 63, fig. 5). A section of an isolated large tooth, which agrees precisely in form with the attached specimen, shews that the arrangement of the folds of the cement and dentine is almost precisely similar to those in the tooth of *Labyrinthodon* (*Mastodonsaurus*) *jaegeri*, as figured in Plate 64 A of Professor Owen's Odontography. I am not acquainted with the structure of the teeth of all other Labyrionthodonts, but those of two at least of the carboniferous genera (*Anthracosaurus* and *Archegosaurus*) differ very markedly from those of the Triassic type genus; in any case, the close resemblance in form of the symphysis of the jaw and of the structure of the tooth of *Pachygnathus* to the same parts in the jaw of the type genus *Labyrinthodon*, which is confined to the Keuper in Europe, affords a strong confirmation of Dr. Feistmantel's view, derived from the study of the flora, as to the homotaxis of the terrestrial forms of life of the Panchet group of rocks with those of the Keuper of Europe.

DICYNODON ORIENTALIS.—*Huxley.*

In a recent paper in the Quarterly Journal of the Geological Society of London (Vol. XXII, p. 98.), Professor Owen expressed his opinion that the foramen in the humerus of *Dicynodon orientalis*, from the Panchet rocks, is probably homologous with the foramen of *Cynodraco major* described in that paper. The Professor was, however, unable to be positive in this assertion, owing to the imperfect specimens figured by Professor Huxley in his above-quoted memoir on the Panchet vertebratæ. From an examination of more perfect specimens now in the Indian Museum, I am enabled to state that the foramen in the

* British Cretaceous Reptiles, Owen,—Palæont. Soc. Phillips'Geology of Oxford.

† Palæontologia Indica, Ser. IV, Vol. I, p. 6.

humerus of *D. orientalis* is "entepicondylar," and consequently homologous with that of *Cynodraco* and not with that of the Lacertilia. On a future occasion I shall hope to give figures of these more perfect humeri, and also of other parts of the skeleton of *Dicynodon* and other vertebratæ from the Panchet rocks.

MYLIOBATIS, Sp.

A specimen of a portion of the dental plates of a species of *Myliobatis* has been sent down by Mr. Wynne from the nummulitics of Kach; this is, I believe, the first recorded occurrence of the genus in Indian rocks. The specimen comprises the greater portion of four of the large median dental plates, and also shows on one side three small and diamond-shaped lateral plates; the small size of the innermost one of the three outer rows of dental plates, the two outer rows being absent, shows that the specimen belongs to the genus *Myliobatis*, and not to *Zygobatis*. The median teeth are rounded transversely, and somewhat hollowed near the middle line and along their outer border; their anterior border is concave. The antero-posterior diameter of these plates measures half an inch; the antero-posterior diameter of the external row of plates is also half an inch, and their transverse diameter three-tenths of an inch.

The plates are larger than those of any of the Bracklesham species of the genus, but most nearly resemble in form those of *M. Edwardsii*, from the middle eocene of that place. I think, however, that the Indian specimen will eventually turn out to belong to a distinct species.

The association of the remains of a species of *Myliobatis* with nummulites, and similar genera of Mollusca, in the eocenes of Bracklesham and Kach, is noteworthy, and serves to indicate that very similar conditions of climate must have prevailed in the two regions at the periods of the deposition of these strata. The genus is not known from strata older than the eocene, and is still represented at the present day.

DESCRIPTION OF A NEW EMYDINE FROM THE UPPER TERTIARIES OF THE NORTHERN PUNJAB, BY W. THEOBALD, *Geological Survey of India.*

Throughout the vast series of beds superimposed on the nummulitic limestone in the Punjab, no remains are more common than fragments of different species of fresh-water turtle, belonging to the families *Emydinidæ* and *Trionychydæ*, though in too fragmentary a condition to be capable of more than generic recognition. During a late examination, however, of the upper Tertiaries south of Jhand, I have obtained two specimens, sufficiently preserved to afford a specific diagnosis. Both specimens consist of the anterior portion of the shell of a fully adult and aged animal, and embrace the three anterior, vertebral and costal plates, comparatively little affected by crust, and one specimen displays (though not very clearly) the ventral surface as far as the inguinal opening: the oval plates being broken away. Both specimens correspond as regards the structure of their plates, the impressed lines marking which are very distinct, though the same amount of individual variation is

seen as is met with in living examples of one species. I propose to briefly characterise it under the name of

BELLIA SIVALENSIS, n. sp.

Testâ depressa quadrate ovata, margine simplici, carinâ vertebrali nullâ. Nuchali nullo vertebrali primo quinque-laterale antice obtuse angulate, lateribus concavis. Vertebrali secundo sex-laterali boleti-formi, antice et postice recto, lateribus antice rotundis, postice, valde concavis. Vertebrali tertio, secundo simili.—Costale primo, magno et medium quinti marginalis attingente. Gularium angulo valde acuto. Sutura pectorali cum post gularibus, fere recto.

Shell oblong ovate, depressed, very flat along the vertebral region and without the trace of a keel, sides shelving, margins simple. Nuchal, none. First vertebral five-sided, with an obtuse angle in front. Anterior sides straight (26 mills), lateral concave (39 mills), base sinuated (26 mills), each vertebral being slightly notched posteriorly to receive a corresponding median prominence in the one following it. Second and third vertebrals equal and similar mushroom-shaped and six-sided. Front and base equal (27 mills). Anterior sides convex, posterior concave. The first costal large, reaching to the centre of the fifth marginal:—

	Mills.
1st Vertebral; greatest width	42
" sides	39
" base	26
" long	50
2nd and 3rd Vertebral; greatest width	50
" base	26
" long	39
1st Costal; greatest diameter	72
" posterior side	55
Gular; broad	22
" long	36
Gular and post gular	42

Marginals sub-equal, the first being the largest.

When perfect the shell must have been close on nine inches long and six broad.

The most obvious characters of this species are the great flatness of the top of the shell, the complete absence of any vertebral keel or nodosity, and the peculiar mushroom-shaped vertebrals. These plates very closely resemble *Bellia crassicollis*, Gray; a species which at present is not known to range north of Tenasserim, but that has a small nuchal plate which is certainly absent in the fossil. Still, however, the two are very similar, the fossil being rather larger than any living specimen of *B. crasicollis* that I have seen.

The geological horizon of the species is a very high one, the fossils having been obtained from a thick series of clays and sands overlying the great gray sandstone series with conglomerates (locally known on the Survey as the 'Dungote sandstones'), and which clays in fact constitute the highest beds of the Siwaliks in the Punjab. Associated with *Bellia sivalensis* are a great variety of fossils, among which it will suffice to specify *Colossochelys*, *Sivatherium*, *Equus sivalensis*, *Hippotherium*, and *Camelus*. These beds

extend for some miles south of the great fault running east and west half a mile south of Jaba (a village 6 miles south-west from Jhand), either horizontal or with a slight northerly dip.

MALOWAL, W. THEOBALD.
22nd January 1877.

NOTE.—The above species of Emydine, according to Mr. Theobald's description, is quite distinct from any specimens in the Indian Museum; in this group of Tortoises I have already determined an *Emys*, an *Emyda*, a *Damonia*, and a *Batagur*, from the Siwaliks, in addition to *Pangshura tectum* determined by Falconer, which I shall subsequently describe.

It is somewhat noticeable that among the very few genera which Mr. Theobald has instanced as shewing the very modern age of the beds from which the new *Bellia* was obtained, that he has mentioned the genus *Hippotherium*, which in Europe is exclusively Miocene and older Pliocene.

R. LYDEKKER.

OBSERVATIONS ON UNDERGROUND TEMPERATURE, BY H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In 1875 two "protected Negretti" thermometers were sent to Dr. Oldham by Professor Everett, Secretary to the Underground Temperature Committee of the British Association. I happened at the time to be working in the Satpura coal-field, where the deepest borings for coal as yet attempted in India are in progress, so one thermometer was forwarded to me by parcel-post. To my great disappointment it arrived broken to atoms, in spite of its triple protection of glass, copper and wood, with cotton padding.* The occasion would not, however, have been propitious for observation, for a double reason: it was advanced in the hot season (March 1875), and it would have been difficult at any hour of the day or night to set the thermometer lower than the degree it would have to register in the hole; and also, the principal boring was in active progress, so that the heat generated by the work would have, to an unknown extent, falsified the ground-temperature.

In the following season (1875-76) I had to take up work in a distant part of India; but early this season (1876-77) I made arrangements to visit the borings at a favourable time. Some untoward circumstances occurred; but in one case, at least, the results are quite reliable, and therefore of interest. Observations were taken in three borings. They are all marked in the annexed table for comparison; but those at Manegaon only can be taken as satisfactory, for reasons that are explained.

Through the kindness of Mr. Wood-Mason I was supplied, in case of accident, with a Casella-Miller deep-sea thermometer (No. 18492). Both instruments were used together in each observation, the Casella above, the Negretti below, the bulbs being fifteen inches apart. The Negretti proved much the more sensitive and steady of the two, as may be seen from the table. There was on an average nearly half a degree index-error between them. All the readings are, of course, on the Fahrenheit scale. In every observation the line was worked very carefully by my own hand, or by my colleague Mr. Hughes. It was lowered very gradually to the required depth, and left at rest a full half hour at that depth.

All the holes are from five to six inches in diameter. At Khappa, the well above the piping, is 10 feet deep, the water standing just below the top of the tube. At Manegaon the well is 8 feet deep, the water standing at 11 feet from surface of ground.

* The protecting glass tube was unbroken, but the thermometer bulb was in fragments, and the stem broken in the middle, the cork disk having parted from the collar of the tube.

Table of temperatures: 5th of December 1876.

Depth in feet.	KHAPPA.		MANEGAON.		MORAN.	
	Casella.	Negretti.	Casella.	Negretti.	Casella.	Negretti.
10		79°·2	80°·8	81·15		
		+1°·0	0·0	−0·05		
20	79°·8	80·2	80·8	81·1		
	+0·7	+0·8	−0·3	−0·10		
40	80·5	81·0	80·5	81·0	82·6	82·1
	+0·4	+0·5	0·0	0·0	−0·1	+0·9
60	80·9	81·5	80·5	81·0	82·5	(c) 83·0
	+0·5	+0·2	+0·5	+0·3	+0·5	0·0
80	81·4	81·7	81·0	81·3	83·0	83·0
	+0·1	+0·3	+0·2	+0·5	0·0	+0·5
100	81·5	82·0	81·2	81·8	83·0	83·5
	+0·5	+0·15	+0·9	+0·9	+0·3	0·0
150	82·0	82·15	82·1	82·7	83·3	83·5
	+1·2 / −0·1	+1·45 / +0·05	+0·65	+0·6	+0·7	+0·9
200	83·2 / 81·9	83·6 / 82·2	82·75	83·3	84·0	84·4
	−1·2 / +0·2	−1·6 / +0·2	+0·55	+0·7	+5·6	+5·45
250	81·6 / 82·1	82·0 / 82·4	83·3	84·0	89·6	89·85
	+2·0	+2·2	+0·9	+0·65		
300	84·1	84·6	84·2	84·65		
	+0·7	+0·55		+0·05		
350	84·8	85·15	(b) 84·3	84·70		
	+0·2	+0·15				
	(a) 85·0	85·3				

Moran bore-hole.—These readings are only recorded to show the disturbing effects of the heat generated by the tools. The work was stopped only four hours before the observations were taken. The general conditions of the bore are very similar to those of the other two, but the increase of temperature is apparent throughout, and the rapid rise near the bottom is very marked. It would, no doubt, have been more so had the observation been taken quite at the bottom, which was still seven feet below the last reading recorded in the table.

(a) In mud at bottom at 370 feet.
(b) At 310 feet, in mud at bottom.
(c) A bump occurred against the end of the tube in raising.
N. B.—The Casella readings may be ignored.

Khappa bore-hole.—As the deepest boring of all, this was the one I was most anxious to observe in; and the failure is partly due to over-caution. At the close of last season (31st May) this hole had reached the depth of 633 feet. I had requested that it might be securely closed; and this was so effectually done that it took five hours battering with hammer and chisel to remove the wooden plug. These shocks must have vibrated through the tube, with which the hole is lined to a depth of 270 feet, and thus disturbed the partially unstable equilibrium in the column of water upon which the result of observations in these small-bore sinkings depends. It would seem even that something more than active convection was thus produced: after the thermometers had been down for fifteen minutes at the 200 feet position, a strong bubbling set up both within and around the tubing, and the water rose three or four inches. This occurred 13 hours after the tube had been opened. The reading then taken (the upper one of the table), at 11 p.m., showed an exceptional rise of temperature; and the next reading, at 250 feet, showed an equally exceptional fall of temperature. Both these points were observed again in the forenoon of the following day, with very different results (the lower readings of the table), and probably nearer to the normal state of the temperature. All the readings, however, about this depth (150′ to 250′), if compared with the corresponding readings in the Manegaon bore, and with the sudden rise in the reading at 300 feet, suggest a zone of slow percolation of surface waters. The necessity to introduce piping to the depth of 270 feet is probably connected with this water-pressure. Nothing was noticed in the samples of rock from these depths to suggest a local cause for such percolation. The sandstones and clays have the same average characters and alternating arrangement as throughout the boring. The reading at 300 feet in Khappa is probably a true earth-temperature. It agrees remarkably with the corresponding one at Manegaon.

Another disappointment connected with the Khappa bore-hole was, that it had filled up with mud to a depth of 260 feet. The observation at 370 feet was the lowest that could be taken.

The observations at Khappa were made on the evening of the 4th and morning of the 5th December. The air temperature was above 90° in the day; 75° at 5 p.m.; and 52° at 10 p.m.; 62° at 8 next morning; and 78° at 10 a.m.

Manegaon bore-hole.—Everything was favourable for satisfactory observations in this boring, except that the hole had silted up to a depth of 110 feet, its full depth having been 420 feet, while the lowest observation obtainable at the time of the observations was 310. It was closed on the 24th of April 1875; so that it had been at rest for 20 months. There is only one guide-pipe, ten feet long, at the top of the bore, there never having been any pressure of water in the hole. The position is low, and the water had always stood at or near the mouth of the tube. There was no difficulty in removing the plug.

The very equable series of temperatures is the natural result of these conditions. The observations were taken in the evening of the 5th and morning of the 6th of December. At 5 p.m., the air temperature was 72°; at 8 p.m., 59°; at 8 a.m., 65°; at 11 a.m. 84°.

The slight decrease of temperature in the top readings is a good proof of the perfectly tranquil conditions of observation. It is no doubt due to the excess of summer heat not yet abstracted; and it is apparent that that influence reaches to a considerable depth—quite to 60 feet. With a specially sensitive thermometer, the range of its variation might, no doubt, be determined with much accuracy in such a boring.

An idea of the climatal conditions may be obtained from the following abstract of observations at the two nearest meteorological stations, kindly furnished to me by Mr. H. F. Blanford. Khappa and Manegaon are two miles apart, and at about the same level, in an

open valley of the Satpuras, traversed by the Dudhi river, south of the wide plains of the Narbada valley, about half-way between Jabalpur (Jubbulpore) and Hoshungabad, which are 150 miles apart. At these two places the temperature-conditions are as follows:—

Monthly Mean Temperatures.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Jubbulpore ...	61·7	66·2	75·1	85·4	90·9	86·7	78·5	77·8	78·5	73·6	66·0	62·0
Hoshungabad ...	66·5	71·2	79·8	88·4	93·3	86·8	78·8	78·3	79·5	77·3	71·5	68·3

Yearly.

Jubbulpore	... 75·2	... 1,351 feet above sea-level.
Hoshungabad	... 78·3	... 1,020 " "

Extremes in 1875 in shade.

Jubbulpore	... Max. 111°	7th June	Min. 34°	3rd February.
Hoshungabad	... " 114°	19th May	" 40°	22nd January.

The elevation of Manegaon may be about 1,400 feet. The mean temperature, I should think, must be quite equal to that of Jabalpur. The extremes are certainly greater; in these more sheltered valleys a strong hoar-frost occurs many nights in January and February; and the heats of summer are also more concentrated. This mean surface temperature is still a very uncertain element of the ground temperature question here.

The geological conditions of the position are favourable for these observations. The rocks consist of steady alternations, in about equal proportions, of fine softish sandstones, and hard silty clays of the upper Gondwana strata having a steady dip of about 10°. The *raison d'être* of the borings is, of course, the conjecture that the coal-measures may be within reach below. There can scarcely be a doubt that they are present, but the depth cannot be estimated with any certainty. Strong trap dykes are frequent in many parts of the stratigraphical basin; but there are none within a considerable distance of these borings. There are no faults near, nor any rock-features having a known disturbing effect upon the heat-distribution.

If, then, we may for the present disregard the uncertain element of the mean temperature at the surface of the ground, and take the constant temperature of 81° at a depth of 60 feet, the readings below that point in the Manegaon bore give a very steady rate of increase of 1° Fahrenheit for every 66 feet of depth. The bottom reading in the Khappa boring may be taken as supporting this conclusion.

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OF

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CONTENTS.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1876. [November.

NOTES ON THE AGE OF SOME FOSSIL FLORAS IN INDIA, *by* OTTOKAR FEISTMANTEL, M. D., *Geological Survey of India.*

VI, VII AND VIII.

VI.—ON THE HOMOTAXIS OF THE GONDWANA SYSTEM.

In the last number of the Records (*supra* p. 79) there is a clearly written paper by my colleague Mr. W. T. Blanford, calling in question the general value of geological homotaxis as drawn from the fossil remains of terrestrial life, and based upon an analysis of the evidence for the age of our Gondwana series. The general question may safely be left to time for settlement. I have no fear that the higher forms of animal and of vegetable life can fail to take their due place in the adjustment of the records of the earth's history—a place proportionate and analogous to their importance in the world; and I therefore regret to see the question brought forward in the unbecoming and unreal aspect of a dispute between geologists and palæontologists.

Regarding the particular case, there is much to be said in correction of it as stated by Mr. Blanford. Perhaps I owe some apology for having left it possible to be so stated; but I had no idea that this discussion would be so precipitately raised, while still the materials for it are under examination. I might otherwise, in the notes already published, have anticipated some of the most serious objections brought forward in the paper under notice. I had postponed these niceties of detailed comparison till the data for it were more completely worked out, being content to state broadly the *facies* of each local flora. I must, however, as briefly as possible, remedy that omission of mine. In doing so it will be necessary to mention undescribed fossils; which, however, I describe shortly in an adjoined paper.

As to the Kach group, I had already fully noticed (*supra* p. 29) as a "palæontological contradiction" the discrepancy between the homotaxis of the group as derived from the plant remains, and as judged from the fossil *cephalopoda*, when we find strata with a middle jurassic flora intercalated with and overlying strata with four *cephalopoda* of Portlandian affinities. It would indeed be rash to question the determinations of the *cephalopoda* by Dr. Waagen; but it must not be forgotten that all the fossil *mollusca* and other fossils are

not yet critically examined; and it is very possible that the full examination of the *fauna* may modify the stratigraphical relations as deduced from the *cephalopoda*, and then the "palæontological contradiction" would not be so strong. To show this, and to explain my point of view, the following observations may be given :—

1.—There are certainly some *mollusca* that are generally of older age than Portlandian, passing into the higher beds of Kach.

a.—I may mention only from the Umia group (which contains the Portlandian *cephalopoda*) the very frequent occurrence of—

Goniomya-V-scripta, which mostly occurs in middle jurassic beds in Europe.

Astarte major, Sow., very near with *Astarte maxima*, Om., from Middle Jura in Germany.

A Trigonia near *Trigonia Vau*, Sharpe, from jurassic beds on the Sunday River in Africa.

A *Goniomya* scarcely different from *Goniomya inflata*, Ag., a Middle Jurassic form—also related with *Goniomya rhombifera*, Goldf., from Liassic strata.

A *Trigonia* very near to *Trig. Herzogii*, Hausm, from Enon on the Sunday River in South Africa.

Some *Trigoniæ* allied with *Tr. ventricosa* in South Africa.

A portion of the lower jaw junction of a *Plesiosaurus*, which has mostly allied forms in the English Lias—found near Borooria in the Umia group.

b.—From the Charee and Katrol beds of Kach, which are especially taken as representing the Oxford group and Callovian, we have especially to mention *Monotis inæquivalvis*, Sow., in Europe generally of Liassic age—here in the Charee beds.

Monotis Münsteri, Goldf., generally in Europe from Middle brown Jura—here in the Katrol group which is taken as representative of the Upper Oxford group.

Parasuchus, a vertebra of that Crocodilian fossil which is looked upon as Triassic, and which occurs frequently with the Jabalpúr flora near Malóri, which latter is identical with our Kach flora.

Near Nurha, in the Katrol beds (therefore below the common plant horizon), the following fossil plants occur :—

Sphenopteris arguta, L. & H., from Inferior Oolite in England—In India occurs in the Rajmahal Series (Rajmahal Hills) and in the Jabalpúr group.

Alethopteris Whitbyensis, Göpp., in the form as *Pecopteris tenuis*, Bgt., from Inferior Oolite in England. Also at Kukurbit and in the Jabalpúr group.

Otozamites comp. *contiguus*, Fstm.—A similar form from Kukurbit.

Araucarites Kachensis, Fstm.—a smaller specimen of this frequent species at Kukurbit and in the Jabalpúr group.

These plant remains are mostly identical with the others from Kach and the Jabalpúr group.

2. There is a great affinity of some of the fossils in the uppermost beds of Kach with forms from the South African strata on the Sunday and Zwartkop rivers as already mentioned; and also Dr. Waagen* refers a *Trigonia* from the Umia beds to the *Trig. ventricosa*, Kr.

* Pal. Indica; Jurassic Cephalopoda of Kach, p. 237.

It is true those beds were first supposed by Mr Krauss* to be lower cretaceous; but this has been shown to be wrong by MM. Bain,† Sharpe,‡ and Tate.‡ Mr. Bain considered those beds as Liassic; Mr. Sharpe, however, and Mr. Tate declared them from the whole of the fossils to be analogous with the great Oolite in England. Also Dr. Waagen speaks of them as Jurassic. With the fossils of those strata many of the mollusca in the uppermost strata of Kach are identical, or very nearly.

Thus it would seem that the decision from the four Portlandian *cephalopoda* may not be final; but if that determination should be confirmed by the whole marine fauna, I will willingly accept the decision, as I have already done in the analogous case of the upper coal seams of Bohemia, where the gas-shale contains Permian animals with a carboniferous flora.

I would next notice some points relating to the lower Gondwana groups, upon which Mr. Blanford's conclusions were rather premature. It will appear—

a.—That the contrast between the floras of the upper and lower groups of the Gondwana system is not so very decided; no more so than between the Jurassic and Triassic formations elsewhere.

b.—That the affinities of our Damuda flora with that of the mesozoic epoch and especially of the triassic formation are overwhelming; and that the arguments for this conclusion are not derived from three species discovered only last year.

c.—That the analogy with the flora of the lower coal strata in Australia is comparatively weak.

a.—*Relation of the floras of the upper and lower Gondwana groups.*

That there is a certain contrast between the flora of the lower and upper portion of the Gondwana Series is, as I think, quite natural, both belonging to distinct formations; the former considered by me Triassic, the latter being Jurassic; but I think the break is not more distinct than between Trias and Lias, or between Trias and Oolite, or even between Rhætic and Oolite in any country.

We find, for instance, scarcely any identical species in the Buntsandstein of the Vosges and in the Lias of the Alps or in the Oolites of England, and we find also no species identical in the Rhætic strata and the Oolitic strata of England.

The triassic strata of the Vosges are, as everybody knows, marked especially by *Schizoneura* and some of the *Coniferous genera* as *Voltzia* and *Albertia*. None of these occur in Lias or Oolite in Europe; and the *Cycads* in the European Trias also are very rare, although not wanting.

Here in India the relation or the passage between the upper and lower portion of the Gondwana Series is palæontologically much better marked—

a.—Indirectly, or by the strata themselves, and especially through the Panchet group.

This contains some rhætic fossils, which formation is altogether a transitive group between the Trias and Lias; our Rajmahal beds being of this latter

* Nova Acta Leopoldina Ac. Nat. Curios., Vol. XXII, Part II, p. 456 ff., Pl. 49, f. 2.

† Transact. Geol. Soc., London, Vol. VII, 2nd Ser., p 175 ff., Pl. XXII, etc.

‡ On South African fossils: Quart. Jour. Geol. Soc., 1867, p. 140 ff., Pls. V—IX.

age.* The Damudas again are closely connected with the Panchet group by that very well marked fossil *Schizoneura Gondwanensis*, Fstm., which is so frequent in both, and which has its only relations in the European Trias.

b.—Directly by fossils.—There are several forms which are common to both, or, at least, which are represented in both.

There are amongst the *Tæniopteridæ* two forms which are very near to some from the Rajmahal Hills, *Macrotæniopteris danæoides*† being very near to *Macrot. lata*, O. M., var. *musæfolia;* both occur very frequent; and some other specimens from Kamthi being near, if not identical with *Angiopteridium McClellandi*, O. M., from the Rajmahal Hills. (This we find in Sir Charles Bunbury's paper‡ as *Tæniopt. danæoides?* McClell.) Both these *Tæniopteris* are found together with the common *Glossopteris.*

Amongst the *Pecopterides* there is *Alethopteris Lindleyana*, Royle, and another form, lately brought by Mr. Wood-Mason from Raniganj (see further on), which belong to the same group as the *Alethopteris indica*, O. M., from the Rajmahal Hills; it is to the mesozoic group of *Alethopteris Whitbyensis* Göpp.

Cycadeaceæ in the lower groups are also not wanting at all, since we know that there is a *Næggerathia Hislopi*, Bunb., from several localities, a *Næggerathia Vosgesiaca*, Bronn, from the Godavari District, and a *Glossozamites* from the Karharbári coal-field. (For these species see further on).

Of course it may be said again that these are genera of wide range, but yet the species are distinct, so is the *Macrotæniopteris lata* and *danæoides* well distinct from *Tæniopt. abnormis* or *Germari* or *multinervis* in the Carboniferous; also *Alethopt. Whitbyensis* and *Lindleyana* from *Alethopt. Serli* or *pteroides* in the Carboniferous; and *Næggerathia Hislopi* and *Vosgesiaca* from *Næggerathia foliosa*, Stbg., from the coal-measures.

There are, moreover, all the other mesozoic relations, as *Phyllotheca, Actinopteris, Sagenopteris*, &c., which are represented in Jura and Rhætic, or in the middle mesozoic epoch of Europe, to which latter the upper portion of our Gondwanas is to be referred.

b—*The affinities of our Damuda flora with that of the mesozoic and especially triassic epoch.*

The first critical discussion of the Damuda flora was given, 1861, by Mr. Oldham§ and later again, 1865,|| where it was endeavoured to be shown that it had a palæozoic affinity, although Mr. Oldham himself acknowledged the exclusively triassic connection of the so

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* Messrs. Oldham and W. T. Blanford have stated this too. Mr. Blanford (Mem. III, p. 133, Raniganj field) says plainly "that the *Panchet Series* represents a period of time intermediate between that of the other two groups (Damuda and Rajmahal"), and Mr. *Oldham* (l. c., p. 204) says—

"The marked break between the Rajmahal and the Damuda rocks, as proved by the total change in their flora, has now, to a certain extent, been filled up by the establishment of the *Panchet group or sub-division intermediate between the two.*"

† Known already by *Royle* and *McClelland*, later brought from *Burgo*, Raniganj, and lately again from Raniganj.

‡ Quart. Journ. Geolog. Soc., XVII: Flora of Nagpúr.

§ Memoirs, Geological Survey, India, Vol. II, p. 324 *et seq.*

|| Memoirs, Geological Survey, India, Vol. III, p. 203 *et seq.*

frequent genus *Schizoneura*. Already, 1861, in a paper by Sir Charles Bunbury* (p. 345), strong doubts are expressed as to this supposition, and the flora of Nagpúr and Burdwan considered rather mesozoic.

In the fifteen years which elapsed since that date, the collections have increased greatly, and we have in all the special collections unmistakable evidence for the supposition of M. Bunbury as to the mesozoic, and, as I add, triassic age of the Damuda flora.

Already in the old collections from Raniganj there were proofs enough. There were *Schizoneura* very frequent, there were one or two *Sagenopteris*, Presl., *Glossopteris*, different from those in Australia. From Kamthi there were specimens of *Tæniopteris* (*Macrotæniopteris* and *Angiopteridium*), of distinct real *Phyllotheca*, like that in the Oolites in Italy; there were again a quite different *Glossopteris* from those in Australia, different not only by the shape of the leaf, but especially by the fructification.

In 1871 some fossils with mesozoic and also triassic affinities were brought by Dr. Stoliczka from Karharbári, amongst which *Voltzia heterophylla* and a *Cyclopteris angustifolia*, McCoy, were at that time determined, and amongst which I have recognised a *Sagenopteris* and a distinct *Glossozamites*.

Again in 1873 an *Actinopteris* was obtained from the Raniganj field, and a collection from the lower Godavari contained some triassic affinities in *Næggerathia Vosgesiaca* and mesozoic affinities in a *Sagenopteris* near *rhoifolia*, Presl. In the season 1873-74, Mr. V. Ball brought from the Satpura Basin the Triassic *Schizoneura*, which was there frequent enough. In 1876 we got some interesting species, which are of great importance as cumulative evidence for the triassic age of our Damudas, especially as they are just from the lowest portion, the Barákar group. These important fossils are from Karharbári, and were presented by Mr. Whitty. They were *Neuropteris valida*, Fstm., *Voltzia heterophylla*, Bgt., *Albertia speciosa*, all triassic forms, and *Gangamopteris cyclopteroides*, Fstm., which is identical with that almost only fossil of the Talchir group, and which has relations in the mesozoic beds in Victoria.

Lately, too, I discovered a real *Phyllotheca*, as that from the Oolites in Italy, amongst the Raniganj fossils. And quite recently Mr. Wood-Mason brought a rather valuable suite of fossils from Raniganj containing further proofs of mesozoic age. I mention especially *Vertebraria*, *Sagenopteris pedunculata*, Fstm.,† *Alethopt. Lindleyana, fructificans*, another *Alethopteris* of the group of *Alethopteris Whitbyensis*, and so on.

To illustrate this relation of our Damuda flora with the mesozoic epoch in general and with the triassic epoch specially, I add here a full list of the fossils, as I know them at present; they are partly contained in my first note, and the description of others are contained in following note, No. VIII; others will be given in the Journal Asiatic Society, Bengal.

EQUISETACEÆ.

1. *Schizoneura Gondwanensis*, Fstm.—Very frequent in the Raniganj group of the Raniganj field and in the corresponding Bijori horizon of the Satpura basin, also in the Panchet group. The only relation is the TRIASSIC *Schizon. paradoxa*, Schimp.,‡ from the Vosges. Never known from Australia.

* Quart. Jour. Geolog. Soc., XVII: Flora of Nagpúr.

† This and other species of Mr. Wood-Mason's collection will be described in the Journal of the Asiatic Society, Bengal.

‡ The genus *Zeugophyllites*, Bgt., which has been confused with *Schizoneura* and of which we find a figure in Strelecki's New South Wales (p. 250, Pl. VI, f. 5), proves by a thorough examination to be a *Zaminæ* of the genus *Zamites* or *Podozamites*, and quite different from *Schizoneura*; so also *Noggerathia* (W. T. Blanford, l. c., p. 83), is no *Schizoneura*.

2. *Sphenophyllum trizygia*, Royle, sp.—from the Raniganj group, Raniganj field, and from the Barákars of Talchir in Orissa.—Completely different from all palæozoic forms.
3. *Vertebraria indica*, Bunb.—In the whole Damuda Series. Some specimens from Raniganj prove the relation with Triassic *Equisetaceæ*. In Australia only from upper coal-measures.
4. *Phyllotheca indica*, Bunb.—The type form in the Kamthi beds, and a specimen from the Raniganj field. Nearly allied forms in the Italian Oolite, with which Australian forms also are connected.
5. *Other* stems of *Equisetaceous* plants in many places.

FILICES.

6. *Actinopteris Bengalensis*, Fstm.—from Raniganj coal-field. In Europe the genus is in rhætic strata.
7. *Neuropteris valida*, Fstm.—from Karharbári coal-field pretty frequent. The only analogous forms are in the TRIAS of the Vosges; single-pinnate *Neuropteris*.
8. *Alethopteris Lindleyana*, Royle.—from the Raniganj field. One species of the mesozoic group of *Alethopteris Whitbyensis*, Göpp. Lately brought in fructification by Mr. Wood-Mason.
9. *Angiopteridium* comp. *McClellandi*, O. M.—from the Kamthi beds, otherwise in the Rajmahal Series.
10. *Macrotæniopteris danæoides*, Royle, McClell.—from the Raniganj and Jheria fields, pretty frequent, and from Burgo in the Rajmahal Hills (Damudas)—Related with mesozoic forms.
11. *Macrotæniopteris Feddeni*, Fstm.—from the Kamthi beds.
12. *Glossopteris (Tæniopteris ?) musæfolia*, Bunb.—from Kamthi beds, different from any Australian form.
13. *Glossopt.* (*Tæniopteris ?*) *stricta*, Bunb.—from Kamthi beds; not like any in Australia.
14. *Glossopt. indica*, Schimp.—from Raniganj and Kamthi; in the latter place with fructification; the globular *sporanges* in 4-5 rows on the leaf surface. Nothing like this in Australia.
15. *Glossopt. leptoneura*, Bunb.—from the Kamthi beds; an Indian species.
16. *Glossopteris*—many other species—not common with the Australian beds.
17. *Glossopteris Browniana*, Bgt.—I must state that I have never seen a good representative of this species from Indian rocks.
18. *Sagenopteris pedunculata*, Fstm. (*Glossopt. acaulis*, McClell.)—from the Raniganj coal-field, lately brought again by Mr. Wood-Mason. Nothing like that known from Australia.
19. *Sagenopteris* comp. *rhoifolia ?* Presl.—from Kunlacheru in the Godavari District. In Europe in Rhætic.
20. *Sagenopteris Stoliczkana*, Fstm.—from Karharbári coal-field. The genus in Europe is Rhætic and Oolitic. No *Sagenopteris* is known from Australia.
21. *Gangamopteris angustifolia*, McCoy.—from Karharbári coal-field. In Australia in the mesozoic rocks of Victoria.

22. *Gangamopteris cyclopteroides*, Fstm.—from the Barákars in the Karharbári coal-field and from the Talchirs. The genus in Australia occurs in the mesozoic rock of Victoria.

23. *Gangamopteris Whittiana* Fstm. from Raniganj field. The genus is mesozoic.

24. *Belemnopteris Wood-Masoniana*, Fstm.—New genus and new species, from Raniganj field.

25. *Palæovittaria Kurzi*, Fstm., nov. gen. and spec.—from Raniganj field.

CYCADEACEÆ.

26. *Næggerathia Hislopi*, Bunb.—from the Kamthi beds.

27. *Næggerathia* comp. *Vosgesiaca*, Bronn—from Kunlacheru, Godavari District. This species, to which our specimen is very near, is in Europe known only from triassic beds.

28. *Glossozamites Stoliczkanus*, Fstm.—from Karharbári coal-field. In Europe this genus ranges from Lias to Cretaceous.

CONIFERÆ.

29. *Voltzia acutifolia*, Bgt.—from Karharbári.
30. *Voltzia heterophylla*, Bgt.—from Karharbári.
31. *Albertia speciosa*, Schimp.—from Karharbári.

} In Europe the most characteristic species of triassic beds.

From what I have said in this section we can draw the conclusion—

That the Damuda flora exhibits itself quite decidedly as mesozoic and most naturally as of triassic age, as out of thirty-one species known at present, there are nineteen distinctly mesozoic forms, of which six species evidently triassic, four species of rhætic, and the others of generally mesozoic affinities.

But also, the other twelve species, amongst which *Glossopteris* is represented by six species, have NO *palæozoic affinities;* and of all the species of *Glossopteris*, only one might be identical with one in Australia.

c.—*What is the analogy of our Damuda Series with the lower coal-measures in Australia?*

This point, as Mr. Blanford truly observes, must be taken into consideration; but the analogy is by no means what he seems to think it.

Any instructive or conclusive comparison can only be made between series that possess fairly represented and characterized flora. For our Damudas this condition can only be said to exist in the upper coal-measures in Australia, and in some exclusively plant-bearing rocks of Europe.

I think those palæontologists who declared the whole Australian flora as absolutely jurassic, did not distinguish the *lower* and *upper* portion of the coal-measures. The first contains forms which could never support this assertion; while the upper measures contain, besides those plants without analogy, some other forms which certainly can justify the supposition of a jurassic age.

On page 83 Mr. Blanford gave a scheme of the formations in the New South Wales coal-field (1, 2, 3, 4, 5, 6). Nos. 1, 2 (Wianamatta and Hawkesbury beds), it is true, have yielded no distinct *Glossopteris;* but in Tasmania, from where identical fossils with those of these

two beds are known, *Glossopteris* occurs with *Pecopteris Australis*, *Phyllotheca*, and the most important, with *Tæniopt. Daintreei*, McCoy. (McCoy: Prodrome, Decad. II, p. 15: Report of Progress, Geol. Survey, Victoria, 1874, p. 25).

As to 3 and 4, of which the first are the upper coal-measures of Newcastle, Mr. Blanford himself (p. 83) says, "Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both, although there *appears to be a considerable distinction in the flora*"; and I would add, No. 3 does not contain any animals, while in No. 4 marine animals are found abundantly.*

On page 84 Mr. Blanford enumerates the species, which, as he considers, are common to our Damudas and the Australian beds, and others which are common to the Damudas and the triassic rocks in Europe (as I pointed out). On these I would remark—

Glossopteris (two or three species identical, W. T. B.)—I think with great difficulty we may be able to get only one common species.

Gangamopteris (the genus only. W. T. B.).—This form is not known at all from those beds intercalated with marine fossils, but from really mesozoic beds in Victoria, associated with *Tæniopteris Daintreei*, McCoy.

Vertebraria (one species identical. W. T. B.)—There is as yet no full description of the Australian *Vertebraria*, and that which is known seems to be quite different from ours. The greatest portion of our Damuda *Vertebraria* are probably not identical with those from Australia.

Pecopteris (*Alethopteris*) (one species probably identical. W. T. B.)—I doubt whether our *Alethopteris Lindleyana* can be united with *Alethopt. Australis*, McCoy; or if this is altogether the case with any other species.

Thus it seems that the evidence of a connection with the Australian coal-measures is very weak, while the fossils enumerated as common with European Trias are unmistakably identical.

As to the stratigraphy of the Australian coal strata—the literature is not poor; but yet it is not in all points quite clear and always trustworthy.

It is well known that there can be a complete concordance in the stratification of rocks, and yet two or more different formations may be represented which can only be distinguished by the prevailing fossil forms. As an instance I can quote the Salt Range in India, where, as Mr. Wynne tells us, the lower marine carboniferous and the triassic rocks are conformably deposited; and yet they are different in age, although a well marked *Ceratites* and *Phylloceras* goes down into the carboniferous rocks, and marked forms of *Belerophon* survived into the Trias. The same relations will have to be applied to the two portions of the Australian coal-measures, only that here the case is illustrated in the flora.

For the stratigraphical grouping of the coal-strata of New South Wales we must especially take Mr. W. B. Clarke's observations, which to a great extent are published:† partly Mr. Clarke communicated them to me in two letters, and he sent also a suite of fossils for

* I speak of this further on.

† Remarks on the Sedimentary Rocks in New South Wales, IIIrd Ed., 1875.

comparison. From all his clear communications it is plain that there are two very distinct portions in the Australian coal-measures—

a.—Upper coal-measures.

b.—Lower coal-measures.

a.—The upper portion is marked by a flora, which is abundant Nos. 1, 2, 3 of Mr. Blanford's list must be referred to this; they contain no marine fossils to indicate a connection with the lower portion.

b.—The lower coal-measures are marked by two marine faunas of, as generally taken, a carboniferous age, which separate distinctly these from the upper beds. The flora is, as both Mr. Clarke and Mr. Daintree state, only rare.

c.—Below this there are beds with real lower carboniferous plants.

The succession of the several strata of the Australian coal formation, as Mr. Clarke communicated it to me in a late paper, and as it is to be found in his "Remarks" (l. c.), is as follows:—

Upper Coal-measures.	Beds in Tasmania, Queensland, Victoria. — Without New South Wales.	No animals.
	Clarence River.	
	Winamatta beds.	
	Hawkesbury beds.	
	Bowenfels.	
	Upper beds in Newcastle.	
Lower Coal-measures.	Beds with marine animals intercalated with plant beds. Especially Stony Creek, Rix. Ck., Greta, Mnt. Wingen, &c.	
	Again marine beds.	
Culm Series	Smith Creek	Lower carboniferous plants with carboniferous animals.
	Port Stefens	
Devonian ...	Goonoo-Goonoo	Plant remains only.

As to the fossils from these several beds I may give an account of those which I have seen, or which are mentioned as really occurring—

a.—Upper coal-measures—

1. From Queensland: *Pecopt. odontopteroides,** Morr., *Tæniopteris Daintreei, Cyclopt. cuneata*, Carr., &c.

   These beds are altogether taken by Daintree as mesozoic, and *Tæniopt. Daintreei*, characteristic of these beds.

2. From Tasmania—prevailing *Thinnfeldia*-like ferns; besides this *Glossopteris* and *Pecopteris Australis*, McCoy.

3. From Victoria—from here we find the following plants described as mesozoic†:—

   Gangamopteris angustifolia, McCoy, *G. spathulata*, *Gangam. obliqua*, McCoy, *Neuropteris* sp.

* I should say this is rather a *Thinnfeldia*.

† See Report of Progress, Geolog. Surv. of Victoria, p. 35.

Pecopteris Australis, McCoy., *Sphenopteris, Tæniopteris Daintreei*, McCoy., *Zamites ellipticus*, McCoy.

Phyllotheca Australis, McCoy.—Here we have real *Phyllotheca* with *Tæniopt. Daintreei*, McCoy.

4. From the Wianamatta and Hawkesbery, we have mostly *Dichopteris, Thinnfeldia, Pecopteris odontopteroides*, Morr., *Tæniopteris*, etc.; and in both the same genus of a fish.

5. From Clarence River District.—*Tæniopteris* with narrow leaves, and a coniferous branch, to which Mr. Clarke himself marked *? Voltzia*.

6. Bowenfels and Newcastle.—Here the flora is mostly developed: *Vertebraria*, real *Phyllotheca*, many *Glossopteris* (but very few identical with those of India), mostly *Gloss. Browniana*, Bgt., coniferous plants near the mesozoic *Echinostrobus*, coniferous seed-vessels and others, but *no animal fossils*, nor lower carboniferous plants.

b.—Lower coal-measures—

I have seen *Tæniopteris* near *Tæniopt. Eckardi*, Germ., *Glossopteris*, small specimens: besides these, there are quoted *Phyllotheca* and *Nœggerathia*. With these are associated carboniferous fossils.

c.—Strata below—with *Cyclostigma Kiltorkanum*, Haught., *Rhacopteris, Sphenophyllum* (real palæozoic form). These I have seen myself. And again a palæozoic (carboniferous) fauna.

From this we see the following:—Only the strata sub. *b* can claim a palæozoic age, containing a prevailingly carboniferous fauna, which already in *c* occurs together with a palæozoic flora. The flora in *b* is very poor, containing only few forms, which* are so frequent in the upper strata; and to use Mr. Clarke's words about the *Glossopteris*, we may say: "There (in the Australian lower coal-beds) it clearly does not govern, but must be subordinate to the fauna;" and further he says, "why might it *(Glossopteris)* not pass into secondary rocks without denying its existence in the Australian lower coal-measures"?

In the last publication, Mines and Minerals of New South Wales, there is a Supplementary Report by Mr. John Mackenzie on the New South Wales coal-fields, in which on Section *b*, is a sketch-section from Newcastle to Port Booral, about thirty miles long. In this the difference in the fossil remains of the upper and lower portions of the coal-measures is plainly indicated, and also that the upper portion and lower portion are, besides all the differences, slightly discordant.

This may be enough for the present paper; some more material would clear off the matter still better. But already from this we see that there is a great difference between the upper and lower portions of the coal-measures in Australia, the former containing only flora of mesozoic affinities, the latter prevailingly a carboniferous fauna, by which they are in connection with the beds below, although some plant forms begin in them, which afterwards are much more developed; but no *Schizoneura*, no single-pinnate *Neuropteris*, no *Sagenopteris*, no *Voltzia*, no *Albertia*, etc., are found.

Our Damuda flora could, at all events, only be compared with this upper portion, and only through the *Glossopteris* and *Vertebraria*, our flora being much more numerous. But, as I have said, there is perhaps only *one* species common; the Australian *Vertebraria* seems to differ from ours, and the *Phyllotheca* in Australia is as well related

* Remarks, etc., p. 165.

with ours as with that from the Italian Oolite, while in our Damuda flora all the other plants are mesozoic and most of them triassic.

That the upper beds in Australia—Wianamatta, Hawkesbery—and the upper Newcastle coal-beds form a connected series is also shown by the occurrence of the same fish, which is not found in the lower strata.

The following table may illustrate the relations :—

Europe.		Lower Gondwanas in India.	Coal-measures in Australia.
Rhæt. ... / Keuper ...	*Upper Trias* ...	Panchet group. (Flora and Reptilia).	a. *Upper coal-measures.* All the strata, as I enumerated them above under 1, 2, 3, 4, 5, 6. *Flora only.*
Grès bigarré / Bunt.-Sanst.	*Lower Trias* ...	Damuda group. Flora only.	
Carboniferous ...	...	... ...	b. *Lower coal-measures.*
Carboniferous ...	...	... ...	*Strata below.*
Devonian ? ...	...	... ...	*Goonoo-Goonoo.*

VII.—Flora of the Jabalpúr group in South Rewah, near Jabalpúr, and in the Satpura basin.

The Jabalpúr group, as indicated in a former note (*ante*, p. 29), is that upper portion of the Gondwana series covering a large area in South Rewah and also in the Satpuras, the two being almost continuously connected by a narrow outcrop skirting the intervening area of overlying trap, and passing through Jabalpúr at the head of the Narbada valley. It derives its name from the place where its fossil plants were first and best known, *i. e.*, Jabalpúr.

Although the stone in which the plants are preserved differs in each of the three positions just named, the fossils themselves do not, plainly showing that we have to deal with but one formation. These beds were formerly placed on a common horizon with those of Rajmahal and Kach; but, as I have already indicated, these must be separated into two groups, an older typified by the Rajmahal group (in the Rajmahal Hills and near Golapili, Godavari District), and a newer containing the Kach series, to which the Jabalpúr group belongs, the fossils of both being identical.

The fact of the Kach and the Jabalpúr strata being placed with the Rajmahal group, which has long since been recognised as most probably Liassic, would, however, show that from the first the fossil plants of Kach have not been considered of so young an age as has lately been inferred from some of the associated marine fossils. When I examined the Kach flora I was not acquainted with that of the Jabalpúr group; but although geographically intermediate between Kach and Rajmahal, and thus presumably likely to exhibit a blending of the flora had there been any community of horizon, as was formerly supposed, the Jabalpúr flora is specifically the same as that of Kach, and confirms the conclusions I had arrived at regarding the age of the rocks. Some recent discoveries in the Godavari region,* where Jabalpúr plants have been found together with reptilian remains and liassic fishes, tend to support those conclusions, as opposed to the impression made from the *Cephalopoda* of the Kach strata.

* Hughes: *supra*, p. 86.

Pecopteris Australis, McCoy., *Sphenopteris*, *Tæniopteris Daintreei*, McCoy., *Zamites ellipticus*, McCoy.

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The Jabalpúr group, as indicated in a former note (*ante*, p. 29), is that upper portion of the Gondwana series covering a large area in South Rewah and also in the Satpuras, the two being almost continuously connected by a narrow outcrop skirting the intervening area of overlying trap, and passing through Jabalpúr at the head of the Narbada valley. It derives its name from the place where its fossil plants were first and best known, *i. e.*, Jabalpúr.

Although the stone in which the plants are preserved differs in each of the three positions just named, the fossils themselves do not, plainly showing that we have to deal with but one formation. These beds were formerly placed on a common horizon with those of Rajmahal and Kach; but, as I have already indicated, these must be separated into two groups, an older typified by the Rajmahal group (in the Rajmahal Hills and near Golapili, Godavari District), and a newer containing the Kach series, to which the Jabalpúr group belongs, the fossils of both being identical.

The fact of the Kach and the Jabalpúr strata being placed with the Rajmahal group, which has long since been recognised as most probably Liassic, would, however, show that from the first the fossil plants of Kach have not been considered of so young an age as has lately been inferred from some of the associated marine fossils. When I examined the Kach flora I was not acquainted with that of the Jabalpúr group; but although geographically intermediate between Kach and Rajmahal, and thus presumably likely to exhibit a blending of the flora had there been any community of horizon, as was formerly supposed, the Jabalpúr flora is specifically the same as that of Kach, and confirms the conclusions I had arrived at regarding the age of the rocks. Some recent discoveries in the Godavari region,* where Jabalpúr plants have been found together with reptilian remains and liassic fishes, tend to support those conclusions, as opposed to the impression made from the *Cephalopoda* of the Kach strata.

* Hughes: *supra*, p. 86.

The flora of the Jabalpúr group is more numerous than that of the Kach beds, but it exhibits the same character and some of the same peculiarities. I will proceed now to describe the plant remains.

A.—EQUISETACEÆ.

As in Kach, we find also in the Jabalpúr group a complete want of any plants of this order; but I think the jurassic period, above the lias, did not, on the whole, abound in equisetaceous plants, the scarcity of them also marking the whole cretaceous epoch until they become again more frequent in the tertiary rocks.

Even in our liassic Rajmahal group the equisetaceous plants were very rare and represented only by *Equisetum Rajmahalense*, Schimp., from the Rajmahal Hills; while in the Panchet group and Damuda series the frequence of equisetaceous plants is represented by the very triassic *Schizoneura*, Schimp.

B.—FILICES.

In the Jabalpúr group ferns are much more frequent than in Kach, and altogether better preserved, the rock being less sandy and micaceous. With the new species I will give a short diagnosis and will indicate shortly the relations, not omitting relations with older fossils than jurassic.

I.—SPHENOPTERIDES.

There is only one species closely allied to a form in Europe only known in the oolite.

1.—*Sphenopteris arguta*, Lindl. and Hutt.

There is little doubt that our specimen must be referred to this species, its greater size only made me hesitate to identify it completely, but the whole habit and form of the leaf, &c., agree. From the Satpura basin.

II.—NEUROPTERIDES.

None of the real *Neuropteris* have been found, but there is another plant which is generally brought in connection with *Neuropterides;* it is a *Cyclopteris*, Bgt., and belongs to that division, distinguished by the name *Baiera*, Braun., which does not indicate more than a mesozoic *Cyclopteris*, Bgt.

1.—*Cyclopteris lobata*, Fstm. [Compar. *Cyclopt.* (*Bajera*) *digitata*, L. and H.]

Folia semicircularia, basi emarginata, cordata (?) margine lobate, lobis (laciniis) ut videtur denticulatis; nervis e basi foliorum radiatim usque ad marginem eggredientibus, dichotomis, ramulis repetito furcatis.

This species already considered by Dr. Oldham a *Cyclopteris* belongs indeed to this genus in the real sense of Brongniart's *Cyclopteris*, of which some mesozoic forms were subsequently ranged with *Baiera*, Br.; while those specimens from the Rajmahal Hills, which I have called *Cyclopteris Oldhami*, Fstm.,* belong to the sub-genus *Cordiopteris*, Schimp.

Our specimen from Jabalpúr resembles that form described by Dr. Schenk as *Dicranopteris Romeri*, Schenk,† which is also a *Cyclopteris* and from rhætic beds. The only difference I see is in the slightly thinner veins. On the other hand it is scarcely to be distinguished from *Cyclopt.* (*Baiera*) *digitata*, L. and H., from the lower oolite in England; especially Lindley and Hutton, pl. 63, f. 1, and Brongniart, Hist. d. végét., tab. 61 bis., f. 2. Our specimen seems to me not to be so deeply lobed.

* Records, Geol. Surv., Ind., 1876, Vol. IX, 2 p. 35.

† Flora der Grenzschichten, &c., 1867, p. 145, Pl. XXI, f. 9.

We have here also again a form which begins in rhætic and goes into lower oolite. Our specimen is allied with both. From Jabalpúr.

III.—PECOPTERIDES.

This family is pretty frequently represented; it also occurs both in Kach and in the Rajmahal series.

Group of Alethopteris Whitbyensis, Göpp.

Two forms represent this group, which is essentially lower jurassic.

1.—*Alethopteris Medlicottiana*, Oldh.

Fronde tripinata, pinnis remotis patentibus, pinnulis integris, striatis; e basi latiore lanceolatis, acuminates basi paulum subdecurrentibus, fere contingentibus. Nervo medio distincto, nervis secundariis sub angulo acuto aggredientibus dichotomis.—(Diagnosis given by me).

This specimen was recognised already by Dr. Oldham as differing from the others of this group. He proposed the name as above, which I will not change, although it has never been published, and I find it only in pencil on the original drawing.

Our species differs from the allied forms in the *pinnulæ*, which begin with a broad base, but become much narrower, giving the whole plant a peculiar appearance; it may be closely allied with *Pecopt. ligata*, Phill.*

2.—*Alethopteris Whitbyensis*, Göpp.

This species we know already from *Kach;* in the present region it is more common and especially in the form described formerly by Brongniart as *Pecopteris tenuis*,† which has, however, already been united by Unger and others with *Alethopteris Whitbyensis*, Göpp.

As I have said, M. Schimper‡ placed all these related forms to the group *Alethopteris Whitbyensis*, Göpp., considering it a truly jurassic type.

Mr. Saporta has done the same; only he established for all these allied forms a new genus, *Cladophlebis*, Sap., which would then contain the following species:—

Alethopteris Rösserti, Aleth. Whitbyensis, dentata, Phillipsi, harburnensis, arguta, recentior, nebbensis, &c., &c., establishing for all these a close relation, as I have shown in my Kach flora.

Our specimens of *Alethopt. Whitbyensis*, Göpp., are from the Satpura basin.

3.—*Pecopteris comp. Murrayana*, Bgt.

A specimen from Jabalpúr recalls this lower oolitic species. I found the same determination written by Dr. Oldham on the original drawing, which I will use in my detailed paper.

Of the *Pecopterides*, therefore, ***all three species indicate*** a lower oolitic age. One is also found in Kach.

IV.—TÆNIOPTERIDES.

Only some fragments represent this family, indicating one of those forms which Schimper placed in his subgenus *Macrotæniopteris*, reserving *Tæniopteris* for the *Palæozoic* forms; amongst these, however, are also some which could be taken as *Macrotæniopteris*, Schimp. I only recall the specimen described thirty years ago by Gutbier as

* Phillips' Geology of Yorkshire, III Edit., Pl. VIII, f. 74.

† Hist. d. végét. foss., 1828, Pl. 110, f. 4.

‡ Trait. de Pal. végét., 1869, Vol. I, p. 569, &c.

Tæniopteris abnormis, Gutb.,* and which also Schimper has placed with *Tæniopteris*, Bgt. But Dr. Sterzel† in Chemnitz, finding this species very closely allied with the rhætic *Macrot. gigantea*, Schenk., and with the liassic species from the Rajmahal Hills [*Macrot. lata*, Oldh. Mor., *Macrot. Musæfolia*, Oldh. Mor. (not Bunbury), and *Macrot. Morrisi*, Oldh. (only partly)] has regarded it also as *Macrotæniopteris*, Schimp. Dr. Sterzel says about these species, so closely allied with *Tæniopt. abnormis*, Gutb., that there is scarcely any difference and only the formation separates them. For me it is a great satisfaction to see forms, which I have declared to be liassic, so nearly related with a *Permian* one. The close relationship of *Macrot. lata*, Oldh. Mor., from the Rajmahal Hills with *Macrot. gigantea*, Schenk., from rhætic, I mentioned already in my first note,‡ and will discuss it more closely in my Rajmahal Flora.

Altogether, *Macrotæniopteris*, Schimp., contains mostly representatives of lower jurassic forms.

1.—*Macrotæniopteris Satpurensis*, Fstm.

Fronde latissima, ut videtur tenera; nervis secundariis approximatis, rectissimis, plurimis indivisis non nullis solum furcatis.

Our specimen is quite fragmentary—only a portion of the leaf-surface is preserved,—but the veins are so peculiar that it can be distinguished by this character—of course scarcely as a peculiar species, only as a variety; it is rather related with those forms described from the Rajmahal Hills, which differ only in having the venation more separated.

Our specimen is from the *Satpura basin.*

V.—DICTYOPTERIDES.

Genus: SAGENOPTERIS, *Bgt.*

1.—*Sagenopteris comp. Phillipsi*, Lindl. & Hutt.

Lindley and Hutton first described this species as *Glossopt. Phillipsi*,§ while Prof. Phillips has mentioned it as *Pecopt. paucifolia*.|| In his last edition of the Geology of Yorkshire, however, he uses the name *Glossopteris Phillipsi*, L. & H. In M. Brongniart's Hist. d. vég., pl. 63, f. 2, we find also two figures of *Glossopt. Phillipsi*, L. & H., agreeing only with Phillip's figure (III. edit., pl. VIII); and both of these differ from Lindley and Hutton's original figure.¶

Later, Brongniart's and Phillip's figures have been correctly placed by Schenk and Schimper again in *Sagenopteris*, Bgt.,** as *Sagenopt. Phillipsi*, Schenk.,†† where Lindley and Hutton's variety is to be placed also. But Schimper does not mention that *Sagenopteris* begins, as is known, in the rhætic and continues in the lower oolite.

Lately I succeeded in getting some species of *Sagenopteris* out of the Damudas, one of which is strikingly near to *Sagenopt. rhoifolia*, Presl., from rhætic (see further on).

* Gutbier: Versteiner ungen, etc., 1837, I, p. 71-73.
† Jahrb. f. Min. Geol. Palæont., 1876, Uber die Tænioptcriden v. Chemnitz, p. 369, etc., pl. v, vi.
‡ Rec. Geol. Surv. Ind., 1876, N. II.
§ Foss. Flora of Gr. Brit., Vol. I, pl. 63.
|| Geology of Yorkshire, I and II edit., Tab. VIII, f. 8.
¶ Vol. I, pl. 63.
** Flora der Grenzschichten, p. 104.
†† Also Count Casp. Sternberg in Fl. d. Vorw. II., p. 165, knew the name *Sagenopt. Phillipsi*.

From the Jabalpúr group there is a *pinna*, of which the veins are disposed in the same manner as in *Sagenopt. Phillipsi*, especially in Brongniart's figure 2, tab. 63 (Hist.). Our specimen is narrower and longer, the midrib quite distinct, the secondary veins passing out of it at an acute angle, are once or twice dichotomous, and join again quite close to the margin. From *Jabalpúr*.

In considering the ferns found in the Jabalpúr group, we have mostly such forms as are found in Europe in the lower oolite, thus :

1.—*Sphenopteris* comp. *arguta*, L. & H.—In England a lower oolitic species.

2.—*Cyclopteris lobata*, Fstm.—Nearly identical with *Cyclopteris digitata*, L. & H., which is lower oolitic in England.

3.—*Alethopteris Whitbyensis*, Göpp.—A lower oolitic species in England.

4.—*Pecopteris* comp. *Murrayana*, Bgt.—In England a lower oolitic species.

5.—*Sagenopteris* comp. *Phillipsi*, Schenk.—A lower oolitic species in Europe.

C.—CYCADEACEÆ.

In the Jabalpúr group we find the *Cycadeaceæ* pretty abundant, more so than in Kach, and with other genera; but here again the genus *Ptilophyllum*, Morr., is found.

Some of the species are true lower oolitic forms; one is liassic.

I.—Zamieæ.

This family alone is represented in the Jabalpúr group, but very frequently. I shall use the generic names as Schimper used them in his Paléont. végétale, and as they are also generally acknowledged.

1.—*Podozamites* (*Zamia-Zamites*) *lanceolatus*, L. H.*

There occur very many detached leaves, long and lanceolate, angustate a little at their base, acuminate on their apex, and with numerous veins. They are identical with *Zamia lanceolata*,† L. & H., or *Podozamites lanceolatus*, Schimp.‡

This is a lower oolitic species, where it has the same place and importance that *Podozamites distans*, Presl.§ has in the rhætic; the veins of the latter, however, are rarer and thicker.

We know this species from all three districts—South Rewah, Jabalpúr, and Satpura basin.

2.—*Podozamites spathulatus*, Fstm.

Foliis brevioribus, ovato lanceolatis, basi attenuatis, spathulatis, nervis paucis, simplicibus.

This form is shorter, ovate towards the apex, and the veins are more distant from each other; in this character this species approaches more to *Podoz. distans*, Presl., of the rhætic. From South Rewah—

3.—*Podozamites Hacketi*, Fstm.

* Foss. Flora of Gr. Brit, Vol. III., pl. 194.

† Trait. d. Pal. végét., Vol. II, p. 159.

‡ Presl. in Sternberg Ver. II, p. 196, Tab. 41, f 1; Schenk. Flor. d. Grenzschichten, p. 159, Tab. 35, f. 10, etc. Schimper Pal. végét., Vol. II, p. 160.

Fronde latiuscula, rhachide crassiore, foliolis (pinnis) approximatis, oblonge lanceolatis, acuminatis, basi angustatis, suboppositis, oblique insertis, nervis creberrimis, ut videtur simplicibus; media in parte costa subdistincta longitudinali e basi usque ad apicem currente.

Two specimens of this species have been brought by Mr. Hacket, which differ from the former in the arrangement of the leaves, their form, the rigidity and disposition of the veins.

Our specimens are so closely allied to Mr. McCoy's *Podozamites Barklyi,** that the want of a decurrent leaf-base and the presence of but one longitudinal rib constitute the only difference. By the want of the decurrent leaf-base our specimens have less resemblance to an *Araucaria* (or *Bowenia*) than Mr. McCoy's. (See *loco cit.*)

The Australian species is from the Bellarine beds (Victoria), which Mr. McCoy considers as mesozoic (oolitic), in which I think he is right.

Our specimens are from the Satpura basin, and are named after Mr. Hacket (of our Survey), who collected them. It is of importance.

1.—*Otozamites Hislopi* (Oldham sp.) Fstm.

(*Zamites Hislopi*) Oldh.,—label on specimen.)

The genus *Otozamites* is frequent enough in the Jabalpúr group, together with *Ptilophyllum*, Morr. The species above is a very good one, and has been named so by Dr. Oldham himself, for which reason I have kept the specific name, placing it among *Otozamites* to which it appears properly to belong. There is, however, no description of this species anywhere. The name is written only with pencil on the label of the specimen. The diagnosis I give myself.

Foliis latiusculis, apicem versus attenuatis; rhachide ut videtur tenui; pinnis rhachidis superficiem tegentibus, alternantibus, basi latioribus, apicemque versus attenuantibus, apice paulo sursam incurvatis obtusis; basi obtuse auriculata, indistincta cordata, puncto uno tantum inserta ; nervis e basi radiatim in folia currentibus, distincte repetito furcatis.

In the form of the leaf-base and in the manner of insertion, it resembles quite closely *Otozamites Goldiæi*, Bgt.,† but the leaves are much shorter and more obtuse.

In the Kach flora I have described one form as very near to *Otoz. Goldiæi*, Bgt., from Kukurbit; it may stand between our *Otoz. Hislopi*, Oldh. sp., and the true *Otozamites Goldiæi*, Bgt.

Our specimen is from the Sher river, Satpura basin.

Besides this species there are several other species of *Otozamites*, Br., of which I will only mention one as important.

2.—*Otozamites* comp. *gracilis* (Kurr sp.) Schimp.

Kurr described this species first as *Zamites gracilis*;‡ it is from the schist with *Posidonia* of the Upper Lias near Ohmden in Wurtemberg.

Schimper described it as *Otozamites*, and this is the only species with which he could compare our *Ptilophyllum*. He says in his Paléontologie végétale: "*Cette espèce rappelle*

* Prodromus of the Pal. of Victoria, Decade I, p. 33, Pl. VIII. f. 1, 2, 5.
† Saporta: Végét. foss. de France, Paleontologie franç. Pl. XCV. f. 1, from lower oolite in England, Yorkshire.
‡ Kurr: Beitrage zur Flora der Juraf. Wurtembergs, 1845, p. II, pl. I, f. 4.

un peu le genre Ptilophyllum des Indes."* And we have this liassic species in our Jabalpúr group, which is of the same age as the Kach series.

There are about three or four specimens which closely resemble *Ptilophyllum cutchense*, Morr.; but they have no decurrent leaflets; the base of the leaflets is a little broader, sub-auricled, and subcordate, attached by the middle of the base only, the veins radiating in the leaflets, and forked within; the leaflets closely set, alternating, having evidently all the characters of *Otozamites*, Br., in which class Schimper has therefore rightly placed it. Dr. Oldham had already determined it correctly.

It still further proves the early age of our Jabalpúr and Kach series. Our specimens are from the Sher river in the Satpura basin.

1.—*Ptilophyllum*, Morr. (*Palæozamia, Endl.*).

This common genus of the upper portion of the Gondwana series occurs, and shows again the relation of this group with the others as belonging to the same epoch. *Ptiloph. acutifolium*, Morr., is the prevailing form.

The only related form of *Ptilophylhim*, Schimper finds, as I mentioned, with the liassic *Otozamites gracilis* (Kurr.), Schimp., and just this genus is the most prevailing and most characteristic of the upper portion of the Gondwana series.

Our specimens of *Ptilophyllum* are from *Satpura basin*.

1.—*Williamsonia conf. gigas*, Carr.†

I have had occasion to mention this interesting and important genus from the Kach series, the Rajmahal series in the Rajmahal Hills, and from Golapili. It occurs also in the Jabalpúr group.

In pl. 53, f. 15, Mr. Williamson gives a section of the restored *involucrum*, with smooth pyriform axis supporting a superficial layer of oblong cells arranged vertically on its outer surface, and with this our specimen from the Jabalpúr group agrees quite well, only that the layer of cells seems to be broader in the upper part. Outside, several of the lanceolate scales are well seen. I will range our specimens provisionally as *Williamsonia* comp. *gigas*, Carr. From the Satpura basin.

We have therefore amongst the *Cycadeaceæ* the following species of great importance:

1.—*Podozamites lanceolatus*, L. & H. sp. Very frequent in all three districts; a lower oolitic species in England; represented in the rhætic by *Podozam. distans*, Presl.

2.—*Podozamites Hacketi*, Fstm., from the Satpura basin. Nearly identical with the Australian *Podoz. Barklyi*, McCoy from mesozoic (oolite).

3.—*Otozamites comp. gracilis*, Kurr.,‡ from the Satpura basin. In Europe an upper liassic form, related a little to *Ptilophyllum*, Morr.

4.—*Ptilophyllum acutifolium*, Morr., from the Satpura basin. Prevailing in the Rajmahal series.

5.—*Williamsonia comp, gigas*, Carr., from the Satpura basin. In England specially a lower oolotic species.

* Vol. II., p. 171.
† Williamson: Transact. Linn. Soc. Vol. XXVI, Pl. 52, 53; Carruthers Transact. Linn. Soc., Vol. XXVI.
‡ Also Dr. Oldham determin.d it to be this species.

D.—CONIFERÆ.

In this class are again some very typical lower oolitic plants, as we have found also in Kach; one species expressing the relation of these beds with the other members of the upper portion of the Gondwana series.

1.—***Palissya indica***, Fstm.(Oldh. & Morr. sp.).*

Ramis distichis alternantibus, foliatis, foliis linearibus patentibus alternis, in pulvinulo decurrentibus distinctissime sessilibus nervo distincto e basi uno sulcis duobus profundioribus limitato (fonctificatione non obvia).

Of the same plant which Dr. Oldham and Prof. Morris figured from the Rajmahal Hills, and which I found later among the Kach flora and from Golapili, some very good specimens occur also in the Jabalpúr group, one of which MM. Oldham and Morris figured already in their Rajmahal Flora (l. c.) as *Taxodites indicus*, O. & M. But later Dr. Oldham himself recognised it to be a *Palissya*, and I will use his specific name. But as MM. Oldham and Morris have given no diagnosis, nor any description, I supply the want. It is very near to *Palissya Brauni*, Endl., from the rhætic. From the Satpura basin.

2.—***Palissya Jabalpurensis***, Fstm.

Ramis distichis (?); crassioribus foliorum pulvinulis tectis ramulis foliatis; foliis æqualibus, oblonge lanceolato-ovalibus, patentibus, remotiusculis; basi constrictis, distincte decurrentibus, pulvinulis oblongis insidentibus; nervo ut videtur unico medio. Amentis in certis.

This species is very characteristic of the Jabalpúr group, and, till now, known only in it; it has the same importance here as *Palissya conferta*, Fstm., in the Rajmahal series. Through this species and one other coniferous plant (*Auracartites Kachensis*, Fstm.), I have recognised the *Ceratodus* beds of the Godavari region as belonging to our Jabulpúr group.† From Jabalpúr.

3.—***Brachyphyllum mamillare***, L. & H.

I take this fossil in the sense of Lindley and Hutton ‡, who figured on Pl. 188 and 219 two specimens. Mr. Schimper thought these forms different from that described by Brongniart and called the British species *Brachyphyllum Phillipsi*, Schimp. §; still I take these specimens to be *Brachyphyllum mamillare*, L. & H.

Our specimens are pretty frequent and do not differ in anything from the English lower oolitic species. Dr. Oldham himself has already written on the figures of some specimens, which I found drawn, the determination: *Brachyphyllum mamillare*, L. & H., which they really are. From Jabalpúr.

4.—***Echinostrobus expansus***, Schimp.

Of this species, so frequent in Kach, several specimens occur. One specially is very well preserved, showing a pretty large branch with branchlets and the characteristic leaves. It is much more complete than any of those from Kach, and, I should say, than any of those figured. While our specimens from Kach agree more with Phillips' figures ||, this specimen from the Jabulpúr group agrees better with Sternberg's¶

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* *Taxodites indicus*, Oldh., Morr. Rajm. Flora, Pl. XXXIII. f. 6—Figure only.

† See Mr. Hughes: Rec. Geolog. Sur. Ind., 1876, N III.

‡ Foss. Flor. of Gr. Brit., Pl. 188, 219.

§ Palæontol. végét., II. Vol., p. 336.

|| Geology of Yorkshire, ed. III. Ed., pl x. f. ii.

¶ Vers. einer Fl. d. Vorw. I. Tab. 38, f. 1, 2.

From South Rewah and the Satpura basin.

5.—*Araucarites Kachensis*, Fstm.

I gave this name to seeds which were pretty frequent among the Kach fossils and which are very closely allied to Mr. Phillips' "Winged seed,"* described later by Carruthers as belonging to *Araucarites*, with the name *Araucar, Phillipsi*, Carr.† Those from Kach I called *Araucarites Kachensis*, Fstm.,‡ in order to distinguish them, although they are very like those from England. In the Jabalpúr group they also occur very frequently, and they are the same as in Kach, so that I shall call them by the same name.

Besides *Palissya Jabalpurensis*, Fstm., Mr. Hughes found this species in the Wurdha coal-field, near Nawgaon. I was, therefore, able to determine this group with certainty.

From South Rewah, Jabalpúr, and the Satpura basin.

Besides these species mentioned, there occur some more coniferous plants that seem to be peculiar, although allied with one or the other of those described.

Amongst the coniferous plants there are, therefore—

1.—*Palissya indica*, Fstm.—an Indian type.

2.—*Palissya Jabalpurensis*, Fstm., characteristic of the group.

3.—*Brachyphyllum mamillare*, L. & H.

4.—*Echinostrobus expansus*, Schimp.

5.—*Araucarites Kachensis*, Fstm.—the three last are lower oolitic forms in England and elsewhere.

Altogether I have now mentioned nineteen species of fossil plants, which may rise to about twenty-four or a little more when I add the species as yet not mentioned. I would here only discuss those that are best determined and correctly compared with other well known forms.

From these nineteen mentioned species there are—

a.—Identical or very closely allied with English lower oolitic species—

1.—*Cyclopteris lobata*. Fstm.,—scarcely different from *Cyclopteris Baiera digitata*, L. & H.

2.—*Alethopteris Whitbyensis*, Göpp.

3.—*Pecopteris Murrayana*, Bgt.

4.—*Sagenopteris comp.*, Phillips, Schenk.

5.—*Sphenopteris comp.* arguta, L. & H.

6.—*Podozamites lanceolatus*, L. & H.

7.—*Williamsonia comp. gigas*, Carr.

8.—*Brachyphyllum mamillare*, L. & H.

9.—*Echinostrobus expansus*, Schimp.

10.—*Araucarites Kachensis*, Fstm., near *Araucar. Phillipsi*, Carr.

Of the other nine species there are—

b.—An upper liassic form :—

1.—*Otozamites gracilis*, Kurrsp.—from Upper Lias near Ohmden in Wurtemberg—the only ally of our *Ptilophyllum*, Morr.

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* Geology of Yorkshire, II. Edition, Pl., x., f. 5.

† Carruthers, Geolog. Magaz., 1869, Vol. VI., p. 6, Pl. II, f. 7—9.

‡ Kach Flora, Palæontol. Indica, 1876.

c.—An Australian type :—

1.—*Podozamites Hacketi,* Fstm.—strikingly close to *Podoz. Barklyi,* McCoy—from Ballarine Rocks (Mesozoic—Oolitic) in Australia.

d.—Two species are Indian types :—

1.—*Ptilophyllum acutifolium,* Morr.—in the whole range of the Upper Gondwana series.

2.—*Palissya indica,* Fstm.—common in the upper portion of the Gondwana series, as in Kach, and in the Rajmahal Hills and Golapili.

e.—One species is peculiar to the group.

1.—*Palissya Jabalpurensis,* Fstm. Known only in these beds.

There are therefore—

10 species lower oolitic.
1 upper liassic.
2 of Indian types.
1 characteristic of the group.
1 Australian (oolitic) type.

The other four are peculiar, but more or less allied with those already mentioned.

If we compare this flora with the other Indian local floras, it has the nearest relation with that of Kach.

Species identical with those in Kach—

1. *Alethopteris Whitbyensis,* Göpp.
2. *Ptilophyllum acutifolium,* Morr.
3. *Williamsonia,* Carr. genus.
4. *Palissya indica,* Fstm.
5. *Echinostrobus expansus,* Schimp.
6. *Araucarites Kachensis,* Fstm. (abundant).

Species identical with those of the Rajmahal series—

1. *Sphenopteris arguta,* L. & H. (an oolitic species).
2. *Ptilophyllum acutifolium,* Morr. (Indian type).
3. *Williamsonia,* Carr. genus.
4. *Palissya indica,* Fstm. (Indian tpye).

Species identical with those in the beds with *Ceratodus,* &c, in the Godavari region; only two species have been found, and both are Jabalpúr forms—

1. *Palissya Jabalpurensis,* Fstm.
2. *Araucarites Kachensis,* Fstm.

From these considerations the following conclusions may, I think, be drawn :—

1. The prevailing fossils are essentially of such kind as we find generally in lower oolite, agreeing with those from Yorkshire; we will therefore have to consider our Jabalpúr group also of the same age. This conclusion is strengthened—

2. By the occurrence of one distinctly liassic species, *Otozamites gracilis,* Kurr sp.

3. By the occurrence of the same group in the Wurdha coal-field with fish and reptilian remains, hitherto believed to be liassic.
4. Amongst the Indian local floras that of the Jabalpúr group has most species common with the Kach flora, suggesting their close correspondence as to age, so that—
5. All conclusions which can be arrived at about the age of the Jabalpúr group may so far be also applied to the Kach series.

Remains of *Lepidotus* and of *Hyperodapedon* have also been found in the *Ceratodus* beds, indicating the same liassic formation.

In a greyish-red fine sandstone beneath the *Ceratodus* beds of Kota Mr. King found some plant remains which I think to be *Palissya conferta*, Fstm. This species being characteristic of the Rajmahal series, it would seem that this horizon also may be distinguishable in that region.

I may here remark that from a cursory inspection I have made of the Kach collections, I do not think they will bear out the inferences based upon the *Cephalopoda* as to the Tithonian horizon of the upper members of the series.

VIII.—Descriptions of new and discussions of some already known but important species from the Gondwana Series.*

In the following pages are given the descriptions of some new species, which to the date of the publication of my former papers were not known to me, although for some years in our collections. During the thorough rearrangement of the Musuem they have been found, and prove very important for further evidence as to the determination of age. Also some species, which were already formerly known, but which occur again in better specimens.

A.—A new Rhætic form of Pterophyllum, Bgt., in the *Rajmahal Hills.*

Amongst those species which are described by Oldham and Morris,† we find already one form which approaches a rhætic species (*i. e.*, *Pteroph. Princeps*, O. M., very near to *Pt. Braunsi*, Sch.); another has even connections in the Permian formation.

I have now to report on another rhætic species—

Pterophyllum comp. *propinquum*, Göpp.

1844. Goppert: Uber foss. Cycadeen, etc. Verh. d. Schles. Gesellsch., p. 132 ff., Tab. I. f. 5.
1867. Schenk: Flora der Grenzsch., p. 215.

In the above quoted paper Mr. Göppert described a true *Pterophyllum*, Göpp., which is especially remarkable by the distant, pretty equal leaflets, passing out from the *Rhachis* nearly quite straightly. He designated it first as from jurassic rocks, which, however, afterwards proved to be rhætic (in consequence of the examinations of Mr. Schenk and F. Rimer).

Amongst the specimens of the older collections of Rajmahal plants in our Museum, there is a (rather fragmentary) specimen, which by the form and disposition of the leaflets can be compared only with *Pterophyllum propinquum*, Göpp. I cannot discuss it further

* I think it necessary to join these descriptions here in a short form, as I refer to the species in the preceding pages; they will, however, be described and figured more closely in the special papers on the local floras.
† Palæontol. Indica, 1862: Flora of the Rajmahal Series in the Rajmahal Series.

here. I would only state the fact: in the Rajmahal flora I will give the description and figure. It increases again the number of forms in the Rajmahal flora, related with similar in the rhætic formation. The specimen is from Bindrabun.

B.—Descriptions of *new and other species* from the *lower portion of the Gondwanas.*

In my first paper I have enumerated only the most known species, but as I have been obliged to refer in the preceding pages to all the forms of the *Damudas*, I feel the necessity of describing or discussing shortly these fossils now.

1.—*The Damuda Phyllotheca connected with the Australian forms and also with that from Oolite in Italy.*

Since writing my preliminary paper on the *Damuda* fossils* I have come across some better specimens of a real *Phyllotheca* from the *Kamthi* beds, and also one specimen from the Raniganj coal-field.

Sir C. Bunbury called this Indian *Phyllotheca Ph. Indica*;† but it is related to the *Phyll.* from the UPPER coal-fields in Australia,‡ I mean the beds above the first marine fauna; and both are related with the *Phyllotheca* of M. de Zigno§ in the Italian Oolite.

Nothing like this is known in the Permian. This and the coal epoch have their own equisetaceous plants. The Permian epoch has been rather poor in equisetaceous plants, while it is known that the Trias period produced them again very abundantly; in this also our Damuda series agree with the Trias.

The occurrence of the same real *Phyllotheca* (*Ph. Indica*, Bunb.) has not till now been mentioned anywhere from the Raniganj coal-field; lately I discovered one specimen of this species.

The great abundance of equisetaceous plants in the Damudas, with prevailing *Schizoneura*, a triassic genus, and with occurrence of the real *Phyllotheca*, so frequent in the Italian Oolite, would therefore again indicate rather a mesozoic (triassic) age.

The same *Phyllotheca Australis*, McCoy, is also known from Victoria together with *Tæniopteris Daintreei*, McCoy, which latter in Queensland is considered as characteristic of the mesozoic (upper) coal beds.||

2.—*Tæniopterides of the Damudas and their connexions.*¶

In my preliminary paper, mentioned above, I have already called attention to some distinct forms of *Tæniopteris*, Bgt., which should indicate a connection between the Damudas and the Rajmahal Series. Since that time I have examined some other specimens, which prove this connection still more, which I will discuss now.**

a.—That species which Sir C. Bunbury figured l. c. Pl. X, f. 2, with the name *Tæniopteris Danæoides* (?) McClell., is not, I think, correctly placed. I have got some other specimens identical with this figure, but they are no *Tæniopt. danæoides*†† (McClell.—Royle.)

* Records Geol. Surv. Ind., 1876, N. 3, p. 63 ff.

† Quart. Jour. Geol. Soc., XVII., p. 335, Pls. X and XI.

‡ McCoy: Annals of Nat. Hist., Vol. 20, p. 152 f.

§ Zigno: Flor. foss. form. Oolith., Pls. VII, VIII.

|| Daintree (and Carruthers) on the Geology of Queensland. Quar. Jour. Geol. Soc., 1872.

¶ See further on the note on Mr. Wood-Mason's fossils.

** Mr. Hughes assured me several times that he brought some nice specimens of *Tæniopteris danæoides*, McClell., from Raniganj, but I never could find them in our collections.

†† Royle: Illustr. Bot. and oth. Nat. Hist. Him. Mount., Tab. 2: McClelland: Report, 1848-49, Tab. 15.

Schimper * has shown another and perhaps more natural place for it; he took it as synonymous with *Tæniopt. McClellandi*, O. M., which he placed in his genus *Angiopteridium*, Schimp. This view becomes quite probable if we compare Sir C Bunbury's drawing (l. c.) with *Tæniopt. McClellandi*, O. M.;† and the other specimens before me seem to confirm the determination.

Sir C. Bunbury's specimens as well as ours are from *Kamthi.*

b.—Besides this there are from the Nagpúr district (Kamthi) several specimens of a much bigger *Tæniopteris* (*Macrotæniopteris*) which have some related forms, but which yet seem to be different.

The top portion recalls especially *Tæniopteris lata*, O. M., l. c., Pl. IV, f. 3, Pl. V, f. 2. But it belongs to the specimens with which it occurred. It recalls also a little Sir C. Bunbury's *Glossopteris musæfolia*, Bunb., l. c. It would agree quite well, only that there are no *anastomoses* at the base of the veins in our specimens, which Sir C. Bunbury states to have observed.

I therefore cannot identify the specimens under discussion with one or the other species mentioned, as there are differences enough to establish a new species, which I will describe as following:—

MACROTÆNIOPTERIS FEDDENI, Fstm.

Fronde simplici speciosissima usque 20 cm. lata, ut videtur, ovato-elongato-elliptica; apice obtusa, quando que emarginata, plerumque irregulariter incisa vel divisa, consistentia subcoriacea, costa in proportione ad frondis latitudinem ac magnitudinem tantum crassiuscula longitudinaliter striata compressa; nervis secundariis creberrimis tenuibus summa in parte (apicem versus) sub angulo acute eggredientibus, marginemque versus plus sursum arcuatis; in parte frondis inferiore fere horizontalibus marginem versus paulo tantum sursum incurvatis simplicibus ac furcatis alternantibus furcatione aut in ipsa basi aut quodam in parte longitudinis nervorum exhibita.

I have named this very interesting species after Mr. F. Fedden of our Survey, who collected it some years ago in *Kamthi.*

Our species holds a middle place between the Permian *Tæniopt.* (*Macrot.*) *abnormis*, Gutb., and the three species of *Macrotæniopteris* from the Rajmahal Hills, and we have, therefore, in our Triassic beds, between the Permian and Jurassic, a *Macrotæniopteris.*

We have, therefore, the following species of *Tæniopteris* in our Damudas—

Tæniopteris comp. *McClellandi*, O. M., from Kamthi. Sir C. Bunbury's *Tæniopt. Danæoides?* should be placed here—a Rajmahal species.

Macrotæniopteris Danæoides, McCl., (Royle)‡, from Burdwan (Royle) from Jherra coal-field (Hughes) and from Raniganj, and from Burgo in the Rajmahal Hills (our coll.).

Macrotæniopt Feddeni, Fstm., the broadest form I know.—From Kamthi.

If we compare the two *Macrotæniopterides* of the Damudas with the Permian and the Rajmahal forms, we have the following series (regarding the distance of the veins):—

1. *Macrotæniopteris Danæoides*, McCl.—Damuda.—(The widest distance.)
2. *Macrot. lata*, O. M.—Rajmahal Hills.
3. *Macrot. Feddeni*, Fstm.—Damuda.
4. *Macrot. abnormis*, Gutb. Permian.—(The narrowest distance).

* Palæont. végét., Vol. I, page 605.
† Rajmahal Flora, (Oldham and Morris), Pl. XXIII, figs. 1, 2, 3.
‡ See further Mr. Wood-Mason's collection.

3.—*A new Gangamopteris from the Kamthi beds and another from Karharbári.*

Of the genus *Gangamopteris*, which McCoy established for some transitious forms between *Cyclopteris* and *Glossopteris*, I described already one species in my first note on the flora of the Damudas and the Talchir group: I called it *Gangamopt. cyclopteroides*, Fstm.,* on account of the more *Cyclopteris*-like form of the leaf. From the occurrence of this species both in the Barákar and Talchir groups, I draw the conclusion that these groups are both of the same age, as the Talchir group contained little else than this species. McCoy described it first from some rocks in Victoria, where no marine fossils occur, but where *Tæniopteris Daintreei*, McCoy, is found, which latter in Queensland is considered as characteristic of the mesozoic beds there. With these also *Phyllotheca Australis*, McCoy, occurred in Victoria.

Now I have also from the *Kamthi* beds very closely allied forms;† they are, however, much smaller, seem to have a thicker substance, thicker veins and wider venations, so that I will describe it as a species of its own. Another species, brought lately by Mr. Wood-Mason, I mention further in the note on the fossils he brought from Raniganj.

GANGAMOPTERIS HUGHESI, Fstm.

Fronde simplici, rotunde ovali, sub coriacea basi ut videtur subcordata, margine intergra, mediocriter longa, maximo specimine 10-11 *cm. longa,* 5 *cm. lato; rhachide vel nervo medio nullo; nervis radiatim e basi usque ad marginem currentibus, arcuatis, nonnulis mediis, omnibus parte inferiori crassioribus, dehinc omnibus repetito furcatis anastomosantibus retia latiora, breviora formantibus.*

I have called this form after Mr. Hughes of our Survey, who has already collected a great many of interesting fossils from the Damuda series.

Although describing this fossil by a name of its own, I yet believe it related with that species from the lower Damudas and the Talchir group, *i. e., Gangamopt. cyclopteroides*, Fstm.

This again supports, what I have already supposed, that all the three sub-groups of the Damudas, although in reality existing, are yet of the same age, and that the Talchir group too is to be subnamed in this epoch.

Another form must be noticed from the *Karharbári* coal-field, it is—

GANGAMOPTERIS ANGUSTIFOLIA, McCoy.

18 . *Cyclopteris angustifolia*, McCoy: Annals and Magaz. of Nat. Hist., Vol. 20.
18 . *Gangamopteris angustifolia*, McCoy: Prodrome of Palæontology of Victoria. Des.

Amongst those specimens which, as I already mentioned several times, Dr. Stoliczka brought from *Karharbári* coal-field, is also a specimen which already at that time was determined as *Cyclopt. angustifolia*, McCoy, which, however, is now by McCoy himself ranged with *Gangamopteris*, McCoy.

This *Gangamopteris* is in Victoria found in certainly mesozoic rocks, being associated with *Tæniopteris Daintreei*, McCoy, which is characteristic of mesozoic rocks in Queensland.‡

* Records Geol. Surv. Ind., 1876, N. 3.

† In my last paper on *Damuda* fossils (Rec. Geol. Surv. Ind., 1876, N. 3) there is wrongly written "that the specimens from Kampti belong to the same species" (as *Gangamopteris cyclopteroides*, Fstm.). It should be written that they belong to the same "*genus*."

‡ Daintree: Geology of Queensland, Quar. Jour. Geol. Soc., 1872.

4.—Some other species of Sagenopteris from the Damudas.

The two species of *Gangamopteris* described above from the Damuda Series are distinctly belonging to that genus. But there are from the Damudas near Kunlacheru in the Godavari district two specimens, about which I am not quite sure whether they belong also to this genus or whether they are rather to be ranged with *Sagenopteris*, Bgt. They recall, it is true, somewhat *Gangamopteris angustifolia*, McCoy,* but I am not sure if this species too has not rather its place in *Sagenopteris*, Bgt. I for my part take those specimens from Kunlacheru as very near to *Sagenopteris rhoifolia*, Presl., as there is scarcely any difference between them and the leaves of this species when they are detached. We have only to compare the detached leaf in Mr Schenk's Grenzschichten, Pl. XII, f. 4, with our specimens and we find no difference.

Another locality of *Sagenopteris*, Bgt., is the Karharbári coal-field, the same wherefrom I enumerated already four species of mesozoic and triassic age. There is a collection of Karharbári plants in our Museum since the year 1871, and Dr. Stoliczka collected them. Fern leaves are very frequent, with an evidently anastomosing venation, which, however, does not pass out from a midrib; the shape and the association of the leaves on the rock urge us to consider the leaves as detached ones, which formerly have been attached to one common stalk. They are, as I suppose, evidently *Sagenopteris*, but differing in shape and size from those hitherto described. I describe them as follows :—

SAGENOPTERIS STOLICZKANA, *Fstm.*

Fronde digitata ; foliis singulis pedicello communi insertis, deciduis, lanceolato spathulatis, 10 *cm. longis,* 35 *mm. latis, basi latiusculis, sine pedunculo distincto ; lateralibus ut videtur in forma differentibus, nervo medio indistincto, nervis secundariis sub angulo acutissimo ad marginem currentibus repetito dichotomis, retia formantibus ; retibus inferiore ac medio parte majoribus, marginem versus, minoribus. Fructificatione non obvia.*

The leaves of this species differ in shape and size as well from *Sag. rhoifolia*, Presl., as from *Sag. Göppertiana*, Zign., but it is allied with both, being a *Sagenopteris*.

I will not make any further discussions here—I will only say that the genus *Sagenopteris* in Europe is known only in Rhætic and Lias, and that it has some connection with *Cheropteris*, Kurr., of the Keuper.

Perhaps also some species of *Glossopteris*, Bgt., are allied; I mention, for instance, *Glossopteris acaulis*, McClell., which should evidently be placed here, and I mentioned it already as *Sagenopteris*, Bgt. The *Tæniopteris*, Bgt., with the real mesozoic aspect and with connections in the Rajmahal Series would support the conclusions to be drawn from the occurrence of *Sagenopteris*, Bgt.

Mr. W. T. Blanford is certainly right in saying that some of these ferns are of wide range; but if we consider it nearer it should be said of the most fossils; but I think also of widely ranged genera some species can be characteristic, and this is especially with the *Tæniopteris* the case, even so with *Sagenopteris* and others, and if some of those genera mentioned are of wide range, it is certainly the more the case with *Glossopteris*, so that there yet remain for the Damudas the other species as—

Macrotæniopteris Danæoides, McClell., certainly mesozoic, frequent.
Schizoneura Gondwanensis, Fstm. (very frequent.)
Sagenopteris, two species—Rhætic genus.
Neuropteris valida, Fstm.—(frequent.)
Voltzia acutifolia and *Albertia speciosa*, Schimp.

* McCoy : Prodrome of the Pal. of Vict., II Decade, Pl. XIII, figs. 2, 2a.

On the four latter of these I will only remark that they in Europe are of triassic age. To these I add now a fifth—

Voltzia heterophylla, Bgt., 1828.

1828. Brongniart: Prodrome.

1828. Histoire des végét foss.

1843. Schimper and Mougeot: Monograf.

1870. Schimper: Paléont. végét.

Amongst the specimens brought by Dr. Stoliczka from Karharbári are also three, which are labelled *Voltzia heterophylla*, Bgt. I cannot know by whom the label was written, but it is certain that already, five years ago, this species was recognized, but since that time, no doubt overlooked. It is the more important, as this species is just from the lower part of the Damudas, *i. e.*, from the Barákar group.*

This species, as every body knows, is the most characteristic of the Trias, of course in Europe only; but I for my part do not give up the same age for it here in India also.

The discovery and determination of this plant agrees very well with those I later made quite independently, as I found the *Voltzia heterophylla*, Bgt., which Dr. Stoliczka brought, after I had written my first paper on the Damuda fossils.

As far as I know, there is nothing known like these or similar plants from the lower coal-measures in Australia, and also in the upper portion is, besides *Glossopteris*, (a genus of wide range) only *Phyllotheca* and the doubtful *Vertebraria* in common with our Damudas, of which, however, the first genus is also in the Oolite of Italy pretty frequent, and the other Damuda fossils have also abundantly representatives in the mesozoic formations of Europe.

So that with the same probability we can suppose a communication with Europe at that early date of Indian life, and this for the whole period from Trias till Oolite.

5.—Cycadeous Plants in the Damudas.

A.—Species of Næggerathia, Stbg.

Already Sir C. Bunbury† described from *Kamthi* a species with the name *Næggerathia Hislopi*, B., of which he knew several specimens, but only one is figured.

Næggerathia was formerly, as were many fossils, a disputed genus; but already Sir C. Bunbury (1861) himself took it rather as belonging to the *Cycadeaceæ*, as I think is now generally acknowledged; and we have in *Næggerathia* a genus belonging to the *Zamiæ*. I will speak, therefore, first of Bunbury's species.

1. *Næggerathia Hislopi*, Bunb.

1861. Quar. Jour. Geol. Soc., Vol. XVII, p. 334, Pl. X, f. 5.

Sir C. Bunbury has figured only one specimen, which is rather fragmentary, from Bharat-wádá. From this locality also several specimens are in our collection. All descriptions, as Bunbury has given them, I can confirm. We have several fragments, from which I can judge that the leaves have been about 14 cm. long, beginning with a narrow base and becoming wider towards the apex, where the leaf is apparently oblique.

From another locality in the Nagpúr district, from Barkoi, there is a specimen of the same *Næggerathia Hislopi*, Bunb., in our collection, which plainly shows that the described

* Of the Survey classification.

† Quart. Jour. Geol. Soc., XVII, p. 334, Pl. X, f. 5.

leaves are only detached and formerly belonged to a common stalk. The specimen mentioned shows two leaves, about 9 cm. long, of the shape as Bunbury described; they are in the same direction lying on one side of a stalk which undoubtedly belongs to these leaves. They were, therefore, attached in the same way as in the real *Næggerathia;* and if we look for a mesozoic *Næggerathia,* we find the same arrangement of leaves in the *Næggerathia Vosgesiacia** Bronn., from the Keuper of the Raibl beds.

Also from the Karharbári coal-field there is one specimen which is to be ranged here.

The leaves of *N. Hislopi,* Bunb., differ from *N. Vosgesiaca,* Bronn. by much stronger veins and by having the margin entire.

Locality.—We have this species, therefore, from Bharat-wádá Barkoi, and from Karharbári coal-field.

2.—*Næggerathia* comp. *Vosgesiaca,* Bronn.

1858. Leonhard and Bronn: N. Jahrb., p. 129, Pl. VI, f. 1-4.
1870-72. Macropterygium Brouni, Schimp.: Pal. végét., Vol. II, p. 132.

There is also another *Næggerathia* from the *Damudas* of Kunlacheru (Godavarí District), which from the first moment I recognized to be a *Næggerathia;* some incised and lacerated leaves with very fine venation are joined on one common stalk, which, however, is partly broken off, so that I was in doubt about the insertion.

The best, and perhaps only, connection of our specimen I found, however, with Bronn's *Næggerathia Vosgesiaca* (l. c.) The author described his species as consisting of a pretty large form with a thick stalk, from which passed out on both sides (partly alternating) the leaves, marked by two characters—

1.—By their fine venation, and

2.—That they are not entire, but divided and incised in different manners and degrees, so that they consist of several *laciniæ* joined together.

All these characters our specimen above mentioned exhibits too, so that I can only bring it in close connection with that triassic species.

The middle *laciniæ* of our leaf are 12 cm. long, the marginal ones only 5·6 cm. The general form is cuneiform, the venation very fine, running radially towards the margin, frequently forked, but the branchlets not much thinner than the main branches. Bronn's drawings do not show this forcation, although Bronn himself describes it.

B.—Another Zamiæ from the Damudas.

Amongst the specimens brought by Dr. Stoliczka there is still another leaf which by the whole form indicates a *Zamiæ.* It can, however, not be referred to *Næggerathia,* the leaf base being quite different, from which it follows that the insertion also differed; we have no stalk, but the leaf is only a little attenuated at the base; it reminds strikingly the genus *Glossozamites,* Schimp†. I have no doubt that ours belongs to it.

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* Bronn: Zur triasischen Fauna und Flora der bituminösen Schiefer von Raibl. N. Jahreb. für Min. Geol. und Pal., etc., 1858, p. 129, Pl. VI, f. 1-4.
† Schimper: Pal. végét. Vol., II, p. 163.

GLOSSOZAMITES STOLICZKANUS. *Fstm.*

Frondis forma ac magnitudo ignota, Foliis elongato ovalibus, validis 8 cm. longis, 23 mm. latis, media parte latissimis, parte apicdli paulo attenuata, rotundata, parte basali æquali modo angustata, truncata, angulis basalibus obtusis; foliis media in parte insertis; nervis creberrimis, distinctis, e tota basi radiantibus, furcatis.

This species has its allies in some forms described by Mr. Schimper with this generic name, but which altogether range only from Lias to lower cretaceous. These species are *Glossozamites oblongifolius*, Kurr.,* from Lias in Würtemberg; *Glossoz. Zitteli, Hoheneggerei*, and *obovatus*, Schenk†.

Our specimen has all the characters of these described species. The largest species till now described is *Glossoz. Zitteli*, Schenk, from lower cretaceous; the leaves measuring 5 cm, 8 mm., while ours are much larger still.

Locality.—Karharbári coal-field, brought in 1871 by Dr. Stoliczka, in the same coal-field from where *Neuropteris valida*, Fstm., *Voltzia heterophyllum*, Bgt., *Voltz. acutifolia*, Bgt., and *Albertia speciosa*, Schimp, are known by Mr. Whitty's discovery.

There is, therefore, no want of *Cycadeous plants* in the *Damudas*, and they are mostly of mesozoic character.

All these supplementary notes were, I think, necessary; and it is probable that still more plants of this kind will be discovered to finally establish the position I have indicated for their formations.

MR. WOOD-MASON'S COLLECTION OF FOSSIL PLANTS FROM RANIGANJ.

I cannot omit giving a short note on some very interesting plants Mr. Wood-Mason lately has brought from Raniganj. They not only exhibit better specimens of already known species, but to a great extent also new forms. As at Mr. Wood-Mason's request I shall write a special paper on them, only a very short note shall be given here.

Macrotæniopteris (Tæniopteris) Danæoides, McClell. (Royle).

The same species which Royle formerly called *Glossopt. Danæoides*, but later McClelland correctly described as *Tæniopteris Danæoides*, McClell., of which he gave two figures, and of which there is a nice specimen in our collection from Burgo in the Rajmahal Hills‡ (Damuda beds), Mr. Wood-Mason found several very nice and well preserved specimens; and his statement is, that this form is there very frequent. All the specimens have a very mesozoic aspect, and strikingly resemble certain specimens from the Lias (Keuper?) in the Alps. Besides this they resemble also pretty much *Tæniopt. lata*, O. M., especially the specimen Pl. II, f. 1, and the variety *Tæniopt. musæfolia*, O. M, Pl. IV, f. 1, from the Rajmahal Hills; again also a further evidence of connection of both portions (upper and lower) of the Gondwana Series.

Gen. *Glossopteris*, Bgt., and *Sagenopteris*, Presl.

Mr. Wood-Mason has brought various specimens of the common Raniganj forms, with narrow net-venations, which I will describe as *Glossopt. communis*, Fstm. But besides these two or three leaves of that species which McClelland called *Glossopteris acaulis*, but which I referred to *Sagenopteris*, Bgt. (as *Sagenopt. pedunculata*, Fstm.)

* Kurr.: Beitr. zur. jura formation Würtembergs. p. 12, tab. I, f. 5, 1846.

† Schenk: Foss. Fl. d. Nordkapathen. Palæontogr, Vol. XIX (1871), tab. I, II, III.

‡ Some nice specimens were, as *Mr. Hughes* has several times assured me, brought by him from the *Raniganj* field, but I never could find them in our collections.

Gen. *Gangamopteris*, McCoy.

I have described already two species from our Damudas. i. e., *Gangamopt. cyclopteroides*, Fstm.,* and *Gang. Hughesi*, Fstm.† Mr. Wood-Mason brought also another, which differs from both by the much wider net-venation, which is also pretty constant in the size of the meshes of the net. I will describe it later with the name *Gangamopteris Whittiana*, Fstm., after Mr. Whitty, who contributed so much last year to our knowledge of the Karharbári flora by the magnificent slab of shale, covered with fine plant-impressions, contributed by him to our museum. I must still once more state that the Australian *Gangamopteris* is from mesozoic strata in Victoria, together with *Tæniopt. Daintreei*, McCoy.‡

BELEMNOPTERIS, *nov. gen.*, Fstm.

Amongst the ferns there is a wonderful specimen, which has its very close connection with the living *Pteris sagittæfolia*, Raddi§, and *Hemionitis cordata*, Roxb. Mr. Wood-Mason's specimen has the same arrow-like shape; three primary veins, the chief primary veins stronger and more distinct; the secondary veins form a net-work of prevailingly hexagonal meshes. This specimen belongs to quite a new fossil genus which I call as above. The species I call in honor of Mr. Wood-Mason, *Belemnopteris Wood-Masoniana*, Fstm. Descriptions and discussions will be given later with the figure of the specimen.

Of other *ferns* there is especially remarkable a very nice large specimen of an *Alethopteris* form of the type of the living *Phegopteris*, a fructificating pinna of *Alethopt. Lindleyana*, Royle, which belongs also to this group.

PALÆOVITTARIA, *nov. gen.*, Fstm.

Another new genus. Of much interest is another specimen with about eleven or twelve leaves coming out (as it seems) from a common spot; the leaves have the form of the mesozoic *Sagenopteris*, Bgt.; they have an evanishing midrib (towards the apex); the *secondary* veins have nearly the same direction, but form *no net-work*, a circumstance which I think will establish this form as a new *genus*, as it cannot be well united with *Tæniopteris*, Bgt.

I do not know anything in the fossil Flora closely similar with it. In the form of the leaves and their disposition there is an approaching similarity with *Næggerathia spathulata*, Dana,‖ from Australia, but there the veins all are radiary, without any midrib.

There is also a slight resemblance with *Chiropteris* from the Keuper¶; but the shape of the leaves, the direction and disposition of the veins, the total want of a distinct *rachis*, and the presence of several thicker veins, distinguish *Chiropteris* from our fern.

I already now can say it is a new genus, allied only with the living *Vittaria*—so that I will call it *Palæovittaria* n. g., and the species *Palæov. Kurzi*, Fstm.

Of other plants I have still to mention several nice specimens of the *Sphenophyllum trizygia*, Ung., which all show again the great difference of the Damuda forms from those in the coal-measures.

These plants, brought by Mr. Wood-Mason, add considerably to our knowledge of the Damuda flora, and have especially yielded again strong evidence of its mesozoic age.

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* Rec. Geol. Surv. India, IX, 3.

† Present paper.

‡ This species Mr. Daintree himself takes as characteristic of the *mesozoic* of Queensland.

§ Ettingshausen: Farren der Jetztwelt, 1865, Pl. 71, f. 3.

‖ Dana: Geology, United States Exploring Expedition, Pl. 12, f. 9.

¶ Bronn: Uber die Farrengattung *Chiropteris*, Kurr. etc., N. Jahrb., f. m. 1858, p. 143, Pl. XII.

To give a complete idea of the flora and its connections, I have given in the preceding Note a general list of all the fossil remains I have so far had occasion to mention from the Damuda beds, which themselves may indicate the age of these beds. I hope there will be added still more of them, but yet these are the most important now, and establish sufficiently the age of the series.

NOTES ON THE OSTEOLOGY OF MERYCOPOTAMUS DISSIMILIS, BY R. LYDEKKER, B. A., *Geological Survey of India.*

Previous notices.—Of this extinct genus of Hippopotamoid Artiocdactyla, which is confined to the Tertiary Strata of India and Burma, no complete descriptions of any part of the skeleton, beyond the teeth, have hitherto appeared. Figures of the cranium, and of some of the limb-bones, have, however, been given in the "Fauna Antique Sivalensis" (*plates* 67 *and* 68), and a short notice of the cranium was given by Dr. Falconer and Sir Proby Cautley in the Asiatic Researches (*vol. XIX*). This paper, together with figures, will be found reprinted in the "Palæontological Memoirs" (*vol. I, p.* 138). In the same volume (*p.* 147, *plate* 15 *figs.* 1 and 2) there is also given a short notice with figures of an adolescent cranium from Burma, forwarded by Dr. Oldham to Dr. Falconer: this specimen is now in the Indian Museum. Professor Owen (*Odontography p.* 566) has also given a figure and a short description of the general characters of the molar teeth; a molar tooth is also figured in M. De Blainville's Osteographie (*Atlas Anoplotherium*); M. Pictet (*Paléontologie, vol.* 1, *p.* 342) has classed the genus, chiefly on account of the form of its molar teeth, with the *Anoplotheridæ*. In Dr. Falconer's above-quoted paper the species was placed in the genus *Hippopotamus*, In the collection of the Indian Museum we have fragmentary portions of several of the limb-bones, from the Manchhars, Siwaliks and Burma beds. From the examination of these, together with Falconer's figures, I have been enabled to arrive at an approximate idea of the skeleton of the genus, though many parts are still wanting, which I hope subsequent discoveries will make good.

Character.—*Merycopotamus* seems to have been a tetradactyle animal of about the size of the Indian wild boar; its dentition has the same formula as in the latter animal, and the excessive development of the canines in both jaws is a character common to the fossil form, to the allied living genera *Sus* and *Hippopotamus*, and to the fossil *Anthracotherium*. The femur followed the normal *Artiodactyle* rule of lacking a third trochanter for the glutæus maximus; while the cuboid and navicular bones of the tarsus were distinct, and the facets on the astragalus for the articulation of these two bones, were of nearly equal size. The radius and ulna were disunited, as in the *Pig*, while in the *Hippopotamus* they are anchylosed together. It will be found that the extinct genus presents points in common with both *Sus*, *Hippopotamus* and *Anthracotherium*, and may probably be regarded as having, like the latter genus, formed a connecting link between the *Suina* and *Ruminantia*. As its name implies, the form of its molar teeth approaches that of the *Ruminantia*, and breaks down the distinction between the "cylindriform" teeth of the true *Pecora*, and the "columno-agglomerate" teeth of the *Suina*; in the Siwalik period, however, these two groups of *Artiodactyla* had already been completely differentiated: we cannot, therefore, consider *Merycopotamus* to have been in any way a progenitor of the true *Ruminants*, but the genus may very probably have descended from some older form, which at an earlier period diverged from an original stock allied to the *Suina*, and gave rise to the more modern and specialized group of *Ruminantia*. From the dimensions of the axis vertebra, *Merycopotamus* must have been a much longer-necked animal than either the *Pig* or the *Hippopotamus*, in this respect also showing *Ruminant* tendencies.

Cranium.—My examination of the cranium has been chiefly confined to the young specimen from Burma noticed above, which from the state of the sutures is in a very favourable state for comparison. The general form of the skull somewhat resembles that of *Hippopotamus*, especially in the long even slope from the occipital crest to the extremity of the nasals, and in the comparatively slight depth of the upper portion of the cranium; the wide zygometic arches and the deep and sharp sagittal crest are also *Hippopotamine* characters. The muzzle is slightly expanded at its extremity, but not to the same enormous extent as in *Hippopotamus*.

Orbits.—The orbits are approximately circular, and completely surrounded by a bony ring; their superior borders are somewhat produced and elevated, forming the highest points on the forehead, while the frontals are considerably depressed below them; in all the above characters the skull of *Merycopotamus* agrees closely with that of *Hippopotamus*, and differs from that of *Sus*. The orbit is placed unusually far forwards, so that its inferior border is directly over the hinder barrel of the first molar: the distal articulation of the jugal reaches as far forwards as the first premolar. In *Hippopotamus* the inferior border of the orbit is placed over the hinder barrel of the second molar, and in *Sus* over the middle of the last molar.

Nasals.—The proximal extremity of the nasals does not extend upwards to within half-an-inch of the inferior border of the orbit; in this respect the skull more resembles that of *Sus*, since in *Hippopotamus* the proximal extremity of the nasals extends upwards beyond the centre of the orbits. The distal extremity of the nasals differs from that of both *Hippopotamus* and *Sus*; in *Merycopotamus* the nasals diminish in width very gradually from above downwards, and terminate somewhat above the extremity of the muzzle; their distal extremity is cut into by an acute re-entering angle; in *Hippopotamus* the nasals narrow very rapidly and terminate directly over the muzzle with a considerable expansion; in *Sus* the nasals narrow gradually and terminate slightly above the muzzle in a pointed extremity. The facial surfaces of the nasals are nearly flat, and placed at right angles to the lateral surfaces of the maxillæ, as in *Sus*; the nasals of *Hippopotamus* are rounded transversely on the facial surface, and do not form any marked angle at their junction with the maxillæ. The greater portion of the outer border of the nasals articulates with the maxilla, and only a very small moiety with the premaxilla; this character forms a marked distinction from *Sus*, and agrees with *Hippopotamus*, only in the latter a rather longer proportion of the nasals articulates with the premaxilla than in *Merycopotamus*; the extremely small proportion of the premaxilla which articulates with the nasals in the latter genus is owing to the relative shortness of the latter bones. The naso-maxillary suture is nearly straight, and thereby different from the same suture in both the allied genera; no portion of the premaxilla overlaps the facial surface of the nasals, as occurs in *Sus*, as distinguished from *Hippopotamus*.

Maxilla and Jugal.—The lateral surface of the maxilla is somewhat hollowed; the foramen for the fifth nerve is placed directly over the last premolar, as in *Sus*; it is situated more anteriorly in *Hippopotamus*. The outer surfaces of the molar teeth are placed so far apart, that the jugal for a long distance along its posterior border becomes continuous with the lateral surface of the maxilla, and does not overhang the latter as is the case in *Hippopotamus* and *Sus*. There is no distinct process of the maxilla for articulation with the jugal, on account of the junction of nearly the whole of the posterior surface of the latter with the maxilla; the form of this portion of the skull is quite peculiar to *Merycopotamus*; the form of the union between the squamosal and jugal is not known.

Lachrymal.—The facial portion of the lachrymal is oblong in shape, and its surface is quite plane; it is considerably elongated antero-posteriorly, so that it articulates with four

bones, *viz.*, the frontal, nasal, maxilla, and jugal. As far as I can make out from the skull of *Hippopotamus* with which I have compared this specimen, in the latter genus the lachrymal articulates with the same four bones, but not quite in the same proportions; in *Sus*, on the other hand, we have a very different relationship of these bones; owing to the shortness of the lachrymal and nasals, these bones do not articulate with each other; but between the two a process of the frontal extends downwards to articulate with the maxilla,—a union which does not occur in either *Hippopotamus* or *Merycopotamus*. The lachrymal foramen is single, and pierces the orbital portion of the lachrymal close to the angle separating the former from the facial portion, a condition intermediate between *Sus* and *Hippopotamus;* the fossils do not, of course, show whether the lachrymal formed a thin capsule within the orbit as in the latter genus.

Frontals.—These bones are depressed, and are united by a straight sagittal suture,—simple inferiorly, but with interlocking processes superiorly; the distal extremity of the frontals forms a slight re-entering angle for the articulation of the nasals; the naso-frontal suture is deeply indented; a small process is given off from the frontals, which is wedged in between the lachrymal and the nasals; in front of the orbits the frontals seem to have been somewhat expanded laterally, but do not form the "telescopic" orbits of *Hippopotamus;* their form was probably more like that of *Sus*. The venous foramina on the surface of the frontals are situated above the centre of the orbits, and pierce the bone at right angles, somewhat as in *Hippopotamus;* in *Sus* these foramina perforate the bone obliquely, and have long sulci below them.

Parietals.—The fronto-parietal suture is not shown in any of the known skulls; the two bones at their union form a bold sagittal crest which divides at its lower third, and runs to the superior angles of the orbits; the surfaces of the temporal fossæ are somewhat convex. The hinder portion of the parietals is very greatly longer in proportion to the size of the skull in *Merycopotamus* than in *Hippopotamus;* the sagittal crest in the former is a long straight ridge for a considerable distance, whereas in the latter it bifurcates to join the orbits after a very short distance. This greater length of the cranial portion of the skull quite does away with the relative excessive length of the nasals, which forms such a remarkable feature in the skull of *Hippopotamus*.

In *Merycopotamus* the cranial and facial portions of the skull are approximately equal, (see plate 67, fig. 5. "Fauna Antiqua Sivalensis"); and from the long sagittal crest the whole cranium has much more the appearance of the cranium of a *Carnivore* than of *Hippopotamus*. In *Merycopotamus* the lateral boundaries of the temporal fossæ are in the same antero-posterior line with the lateral borders of the orbits, whereas in *Hippopotamus* the latter reach outwards to the zygomatic arches.

Occiput.—The form of the occipital surface approaches nearer to that of *Sus* than *Hippopotamus*; the occipital crest forms a bold ridge, angulated in the centre, and somewhat overhanging the general surface of the supra-occipital. The breadth of the supra-occipital is less in proportion to its height than in *Hippopotamus*, and thereby approaches to *Sus:* further, the occipital surfaces of the squamosals are placed considerably more in advance of the plane of the supra-occipital than in *Hippopotamus*, thereby giving the latter bone a more prominent and isolated character, similar to that of *Sus*. The bony ridge connecting the extremity of the occipital crest with the zygomatic process of the squamosal is placed somewhat higher up on the occipital surface, and is larger and stouter than in *Sus:* the prominence of the zygomatic process of the squamosal which overhangs the meatus auditorius externus is wanting in *Merycopotamus*. The supra-occipital is an oblong bone, with its superior extremity produced into a median angle; the ex-occipitals and paramastoid

processes are in too damaged a condition in our specimens for comparison. The basi-occipital is triangular in shape; it is more rounded from side to side than in *Sus*, but it lacks the median groove and the two tubercles which are found on the same bone in *Hippopotamus*.

Bulla tympani.—There is a large somewhat ovate tympanic bulla, larger than that of *Hippopotamus*, and more like that of *Sus*: the meatus auditorius externus is apparently tubular, and directed upwards, backwards, and outwards.

Palate.—The palatines are produced backwards behind the last molar in the same manner as in *Hippopotamus;* their hamular processes have also the same shape and direction; the palato-maxillary suture, as far as I can make it out, seems to have extended as far as the line which divides the first and the second molars; its upward bend is rounded, as in *Sus:* in *Hippopotamus* it is elongated. The two lines of molar teeth are nearly parallel, as in *Sus;* they do not diverge anteriorly, as in *Hippopotamus*.

Glenoid cavity.—The glenoid cavity of the squamosal is flat, and of large size; it has no process of the jugal bordering its outer side; in the latter respect it agrees with *Hippopotamus* and differs from *Sus*.

Mandible.—The rami of the mandible are nearly straight: the distal extremity is rounded off: the symphysis is long, and slightly excavated; it extends backwards as far as the first premolar; it is somewhat expanded at the alveolus of the canine tooth; the condyle and ascending portion is not known; the posterior extremity descends below the inferior border of the horizontal portion, as in *Hippopotamus;* there is a deep notch in front of the descending plate. From the above characters it will be seen that the mandible is entirely *Hippopotamine* in character, and broadly distinguished from those of both *Sus* and *Anthracotherium*, in which the inferior border is nearly straight.

Dentition.—The dental formula most probably was the same as in *Sus* and *Hexaprotodon;* as much of the dentition as is known is given below, *viz.:*—

$$\text{I}\ \frac{?-?}{3-3}\qquad \text{C}\ \frac{1-1}{1-1}\qquad \text{P}\ \frac{4-4(?)}{4-4}\qquad \text{M}\ \frac{3-3}{3-3}$$

Incisors.—The incisors are at present unknown; from the shape and direction of their alveoli they must have been of comparatively small and equal size; they were in close opposition and probably projected obliquely from the jaw, their cutting edges forming a segment of an ellipse. There is no sign of any abnormal development in any of them, and they must therefore have approximated much more closely to *Sus* than to *Hippopotamus*.

Canines.—The canine is situated close behind and a little to the outer side of the third incisor; its inner border is in a line with the molar series; in both of the above respects it agrees with the canine of *Sus*, and differs from that of *Hippopotamus*. The cross-section of the canine is trihedral; two angles are placed in the antero-posterior line of the jaw, and the third on the inner side; these teeth are somewhat curved, the upper one more than the lower; they are not of larger size than the canines of the wild boar; the upper canine does not present the groove on its posterior surface which occurs in the corresponding tooth of *Hippopotamus*.

Premolars.—There is a considerable diastema between the canine and the premolar series; there is no jaw known which contains the whole of the latter series *in situ;* the first premolar seems to have been implanted by a single fang, and was probably of very small size; the last three premolars were implanted by two fangs each. The hinder premolars are unsymmetrically conical teeth, of which the inner surface is flattened and nearly vertical; there are two grooves, and an intermediate ridge on this surface; the outer surface is rounded: there are semi-trenchant edges at the junction of these two surfaces, looking fore-and-aft: there is an accessory column at the antero-internal angle; the enamel is marked

with irregular longitudinal striæ; there is a slight wavy cingulum surrounding the base of the crown. The premolars are strikingly like those of *Anthracotherium.*

Upper molars.—The upper molars are nearly square-crowned teeth, surmounted by four unsymmetrical cones (*specimens figured in "Fauna Antiqua Sivalensis" plate* 62, *fig.* 17, *and Owen's "Odontography," plate* 140, *fig.* 8). The cones are separated by a cruciform valley, of which the transverse division is by far the deeper; the general type, therefore, on which the tooth is formed is the same as that of the simpler teeth of *Sus, Tetraconodon,* and *Hippopotamus.* On the inner sides both inner and outer cones are perfectly symmetrical; the outer surfaces, however, of both pairs of cones are concave; these surfaces of the inner cones are simply concave, while the same surfaces of the outer cones have a median ridge running down the concavity, and a shorter lateral ridge at each of the outer angles of the cone. By this means a *Ruminant* form of the tooth has been engrafted on the original simple form; in *Ruminants* the transverse valley becomes almost obliterated by the approximation of the cones, and only remains as the groove separating the inner divisions of the cones (or barrels); on the outer side the transverse valley does not penetrate the crown, and its place is only marked by the division between the summits of the lobes; further, the antero-posterior valley becomes deeper between the cones (or barrels) and is divided into two portions by the united edges of the inner cones; the outer surfaces of the barrels, instead of being concave and sloping towards the inner side, as in *Merycopotamus,* become flat and vertical, retaining, however, the ridges found on the tooth of *Merycopotamus.*

The upper molars of *Merycopotamus* are surrounded by a distinct cingulum, less boldly marked on the outer surface than on the other three; and their enamel is rugose.

Compared with Hyopotamus.—The molar teeth of *Merycopotamus* are distinguished from those of *Hyopotamus* (another *Hippopotamoid* genus, showing *Ruminant* affinities in the form of its molar teeth) by those of the latter being less altered from the original *Tetraconodon* type; in the teeth of *Hyopotamus* the ridges which occur at the outer angles of the outer pair of cones of the molars of *Merycopotamus* are absent: in consequence, the outer border of the molars of the former genus forms a simple wavy line. There is also in the teeth of *Hyopotamus* the absence of the vertical ridge occupying the middle of the external surfaces of the outer cones which occurs in *Merycopotamus.* The inner cones, moreover, in the European genus are less concave on the outer side, and more regular in shape than in the Indian genus; while the former are further distinguished by the presence of a small additional cone in the re-entering angle on the anterior side of the first pair of cones. The molars of *Merycopotamus* are distinguished from those of *Dichodon* (with which Pictet compares them) by the completeness of the transverse valley in the former.

Lower molars.—The lower molars, like the upper, are intermediate between those of the *Pig* and *Ruminants;* they consist of four cones, of which the outer pair are the highest, separated by a cruciform-valley, of which the transverse portion is by far the deeper; the latter valley is shallower at the inner than at the outer side; the external surfaces of both inner and outer cones are nearly vertical; the inner surfaces of the outer pair of cones are concave; the posterior surface of the hinder one of the outer pair of cones is vertically grooved; an indistinct cingulum surrounds the base of the crown; there is no accessory tubercle at the outer extremity of the transverse valley; following the usual rule of the *Artiodactyla,* the third lower molar has three lobes, the hinder lobe consisting of a single cone, which corresponds to the outer cone of the middle pair.

The teeth are distinguished from those of *Sus* and its allies by the greater width of the transverse valley, and by its becoming shallower at its inner extremity, and by the longitudinal valley being broken up into two portions, which form the pits between the outer and inner cones.

The lower molars are distinguished from those of *Ruminants* by the transverse valley extending completely across the crown, instead of being confined to the outer side; whereas in *Ruminants*. the outer pair of cones are united nearly up to their summits, instead of only at their bases, as in *Merycopotamus;* further, the summits of the cones in *Ruminants* become wider, and the central infolds of enamel (the remnants of the primitive longitudinal valley) become deeper, and are connected together only by a narrow neck, which soon becomes obliterated by wear, causing the enamel pits to become complete islands, which remain until the tooth is worn down nearly to its base; islands only appear for a very short period on the crowns of the teeth of *Merycopotamus,* owing to the shallowness of the enamel folds. In the molars of animals like the *Giraffe* and *Brematherium,* where the enamel pits are connected together by a deep median fold, and consequently are a long period in becoming completely insulated, we have a remnant of a more generalized type of tooth, showing traces of the persistence of the primitive longitudinal valley of the Suine teeth.

Measurements of skull.—The following, measurements are taken from the cranium, figured in the "*Fauna Antiqua Sivalensis*" (plate 67, fig. 1):—

	In.
Length from occipital crest to superior angle of orbit	6·0
Width at superior border of orbits	4·0
Length of orbit	1·9
Width across zygomatic arches	7·4
Width at temporal fossæ	3·7
Length from foramen magnum to free border of palatines	4·4
Length from foramen magnum to last premolar	8·1
Width of palate at second molar	1·9
Length of three molars	3·25
Length of last molar	1·24
Width of ditto	1·2
Length of second molar	1·0
Interval between inferior border of foramen magnum and summit of occipital crest ...	4·1
Width of widest part of supra-occipital	2·7
Interval between external surfaces of occipital condyles	2·85
Vertical diameter of foramen magnum	1·05
Transverse ditto	1·4
Length of occipital condyle	1·3

The dimensions of the skull of the adolescent animal from Burma (No. 212) mentioned above, as given by Dr. Falconer ("*Pal. Mem.*" *vol.* 1, *p.* 148), are as follows:—

	In.
Width of nasals at base	1·9
Extreme length of fragment	7·5
Greatest contraction of muzzle	1·2
Length of two (1 and 2) true molars	1·9
Ditto of two last premolars ... ... about	1·3

The dimensions of the lower jaw figured in "*Fauna Antiqua Sivalensis*" (plate 67, fig. 4), are as follows:—

	In.
Extreme length	13·5
Depth at middle of last molar	2·45
Ditto at second molar	2·9
Depth of descending angle below last of molars	4·3
Length from hinder extremity of last molar to canine	7·9
Length of symphysis	4·4
Interval between canine and symphysis	1·4
Thickness of inferior border below last premolar...	1·02
Length of last molar	1·6
Width of ditto	0·9

The dimensions of the hinder half of a right ramus of the mandible (No. 215) brought by Mr. W. T. Blanford from the Irrawadi valley are as follows:—

	In.
Length of three molars	3·25
Length of last molar	1·6
Width of ditto	0·8
Length of second molar	1·0
Depth at middle of last molar	1·8
Ditto at second molar	2·0

Other specimens from the Potwar country present similar dimensions to the above. These dimensions are smaller than those of the first specimen, the jaw being of a more slender type; the teeth, however, in the two are of the same size. Falconer conjectured that there were two varieties, major and minor. I think, however, it is more probable that the slighter jaws (and crania) belonged to female individuals and not to a distinct variety.

Axis.—The only portion of the vertebral column of *Merycopotamus* which I can identify is the axis vertebra, of which we have two specimens in the Indian Museum (Nos. 1638-39). These specimens only show the centrum, and portions of the pedicles, the neural arch being in both cases destroyed. The centrum has a broad and conical odontoid process laterally continuous with the articular facets for the atlas; the centrum is longer than broad; the inferior borders of the articular facets for the atlas form an almost continuous arch across the anterior extremity; there is a prominent straight keel along the inferior surface of the centrum; the inferior bar of the transverse process is long, and takes its origin about half-way up the vertebra; it is separated by a smooth space from the articular facet for the atlas, and is directed backwards and outwards; of the superior bar of the transverse process only the base is shown in our specimens; this is very wide and situated on the pedicle of the arch a little higher than the floor of the neural canal; the transverse process is perforated for the vertebral-artery. The exterior extremity of the pedicle is perforated for the upper branch of the spinal nerve. The posterior surface of the centrum is slightly hollow, wider than deep, with a horizontal upper border, and a curved inferior border.

The vertebra is at once distinguished from that of either the *Pig* or *Hippopotamus* by its much greater length in proportion to its breadth: in both the former animals the width of the posterior surface of the centrum is equal to two-thirds of the total length of the vertebra; whereas in *Merycopotamus* the width of the corresponding surface is less than half the total length of the vertebra.

Comparisons.—The axis vertebræ of the three genera have the following points in common: the transverse process is perforated by the vertebrarterial canal, and the pedicle by the foramen for the spinal nerve; the odontoid process is bluntly conical, the inferior surface of the centrum keeled, and the inferior bar of the transverse process is separated by a smooth surface from the articular facet for the atlas. The axis of *Merycopotamus* is distinguished from that of *Sus* (besides the difference of length) by the rim connecting the inferior borders of the facets for the atlas being less distinctly continuous below the odontoid process; by the odontoid process being wider and flatter; and by (in consequence of the greater length of the vertebra) the transverse process being much wider, and consequently the vertebrarterial canal much longer. It is distinguished from the axis of *Hippopotamus* by its greater proportionate length and the lesser development of the rim connecting the facets for the atlas; the transverse process is also slightly wider.

Dimensions.—The dimensions are compared below with those of the axis vertebra of the *Pig; Merycopotamus* in the first, and *Sus* in the second column:—

	In.	In.
Length of centrum	2·8	1·7
Width of posterior surface of centrum	1·2	1·2
Depth of ditto	0·9	0·8
Width across anterior articular facets	2·2	2·2
Width of transverse process	0·75	0·3
Length of odontoid process	0·6	0·6
Width of ditto	0·7	0·5

Hinder limb.—Of the hind limb, more or less complete portions of the following bones are known, either from the specimens in the British Museum (from which Falconer's figures are taken) or from specimens in the Indian Museum, *viz., Innominate, Femur, Tibia, Calcaneum, Astragalus, and Metatarsus.*

Innominate.—The innominate is known from the specimens of the acetabulum figured by Falconer ("*F. A. S.," pl.* 68, *figs.* 1 *and* 2); the acetabulum is completely circular and moderately deep, with a distinct pit for the attachment of the ligamentum teres; its diameter is 1·55 inches.

Femur.—At the proximal extremity the great trochanter is placed higher than in *Sus* and *Hippopotamus;* it is also more recurved, and the head is placed more nearly perpendicularly to the neck; it does not show any distinct impression for the ligamentum teres; the digital fossa is also deeper than in the allival genera. The distal extremity of the femur (*see Falconer's figures*) is very different from that of the *Pig* or *Hippopotamus*, and is unlike that of any living Ungulate; the trochlear surface for the paltella is unusually elongated, and its borders are placed almost parallel to the long axis of the bone, instead of very obliquely, as in other Ungulates: the condyles are consequently nearly equal-sized and symmetrical.

Tibia.—The proximal extremity alone of the tibia has been discovered: the articular surfaces are nearly equal sized and symmetrical: the prominence for the crucial ligaments is bifid; there is a notch and prominence on the anterior border as in *Sus:* in *Hippopotamus* this border is roughened, but not notched. On the posterior border in *Merycopotamus* there is a narrow notch, which is not found in the other genera.

Astragalus.—Several views of the astragalus are given in plate 68 of the *Fauna Antiqua Sivalensis*, and we have several specimens of the bone in the Indian Museum, chiefly collected in Sind by Mr. Fedden; the specimen that I have measured is from the left side. The astragalus of *Merycopotamus* is formed on the same general plan as the corresponding bone of *Hippopotamus* and *Sus*, having distinct sub-equal facets for the articulation of the cuboid and navicular bones separated by an intervening ridge, which indicates the non-union of the two latter bones. Comparing the astragalus of *Merycopotamus*, firstly with that of *Hippopotamus*, we find that the former is distinguished by its greater length in proportion to its breadth, so that the breadth of the distal extremity is only equal to one-half the length of the bone, whereas in *Hippopotamus*, the corresponding breadth is equal to rather more than two-thirds of the length of the bone. In both bones the calcaneal half of the tibial trochlea is considerably the highest and stoutest of the two; the trochlear surface for the calcaneum is almost square in *Hippopotamus*, while it is oblong in *Merycopotamus*, and there is a deeper pit between this surface, and the commencement of the tibial trochlea. The articular surface for the cuboid in both is placed on a lower level than that for the navicular, while the latter extends further up on the posterior surface of the bone: both articular surfaces are of approximately equal width, and the ridge between the two is placed obliquely to the long axis of the bone. The lateral surfaces of the two bones have the same general

characters. The astragalus of *Merycopotamus* is distinguished from that of *Sus* by its greater proportionate length, and by the articular surfaces for the navicular and cuboid being of nearly the same width, instead of that for the cuboid being only one-half the width of that for the navicular: further, the trochlear surfaces for the tibia are of nearly equal height in *Sus*. The great proportionate length of the astragalus of *Merycopotamus* is a character which it has in common with that of the *Actiodactyle Anoplotherium*. Below, the admeasurements of the astragali of *Hippopotamus sivalensis, Merycopotamus dissimilis*, and *Sus scrofa* are compared:—

	Hippo.	*Meryco.*	*Sus.*
	In.	In.	In.
Extreme length	3·9	2·25	1·75
Width across tibial trochleæ	2·35	1·0	0·9
Width across distal extremity	2·35	1·25	1·0
Width of cuboidal articular facet	1·35	0·60	0·35
Width of navicular articular facet	1·5	0·66	0·65
Length of calcaneal trochlea	2·45	1·35	0·95
Width of ditto	1·95	0·75	0·65

The astragalus of *Anthracotherium* has the facets for the cuboid and navicular of unequal size, as in *Sus*, and is therefore at once distinguished from that of *Merycopotamus*. Falconer once considered the two genera identical.

Calcaneum.—The calcaneum, as appears from Falconer's figures, appears to be of exactly the same form as the corresponding bone of *Hippopotamus*. It is distinguished from the calcaneum of *Sus* by its anterior surface being broader, and the whole shaft stouter, by the surface for the attachment of the tendo achilles being excavated in the antero-posterior line, instead of being convex, and by the facet for the articulation of the saddle-shaped trochlea of the astragalus being placed more obliquely. The length of the bone is 4·8 inches, and the width of the surface for the astragalus 2·3 inches.

Metacarpal.—The metacarpals are only known to me from the distal extremity of one of the middle bones brought by Mr. Fedden from Sind; the form of the fragment is essentially *Hippopotamine* and not *Suine*. The articular surface forms three-fourths of a cylinder; on the anterior surface there is no ridge on this cylinder, but on the posterior surface there is a marked ridge dividing the cylinder into two nearly equal portions: the shaft of the bone is nearly as thick as the cylinder. In the sub-equality of the portions of the cylinder on either side of the ridge, and in the limitation of the latter to the posterior surface, the bone agrees with the metacarpals of *Hippopotamus*. In *Sus* the ridge extends completely round the articular cylinder, and it is placed very much nearer to the median line of the foot, rendering the two articular surfaces very unequal. From the small extent of the ridge on the metacarpal of *Merycopotamus*, the first phalange of the digits has no distinct groove on its proximal surface: from the nearly median position of the ridge on the metacarpal, the foot must have been less symmetrical in relation to a line separating the third and fourth digits than in *Hippopotamus* and *Sus*; the general form of the metacarpal is very similar to the corresponding bone of *Anthracotherium*; width of distal extremity 0·65 inches.

First phalange.—Of the second phalange of the third or fourth digits we have several specimens in the Indian Museum: the bone is similar in shape to the corresponding bone of *Hippopotamus*, having the superior surface wide transversely, and hollowed, with prominent ridges on the fore-and-aft border; there is a very slight ridge running antero-posteriorly across the middle of the same surface. The anterior surface of the bone is rounded, and the posterior flat: the distal extremity presents a simple trochlea hollowed in the middle line, and extending further up on the posterior surface than on the anterior

surface. Length 1·5 inches; transverse diameter of proximal surface 0·7 inch; antero-posterior diameter of proximal surface 0·6 inch; transverse diameter of distal surface 0·55 inch.

Forearm.—Of the forearm, we only know at present the humerus from its two extremities, the radius, and the distal extremity of the ulna; the two former bones are figured by Falconer.

Humerus.—At the proximal extremity we distinguish the humerus from that of *Hippopotamus* by the great tuberosity being less developed, which renders the bicipital groove less closed in by bone: the bicipital groove is unusually wide, and the deltoid ridge strongly marked; the posterior extension of the great tuberosity forms a more continuous rim round the outer border of the superior surface than in either *Hippopotamus* or *Sus.* The distal extremity agrees with *Hippopotamus*, and differs from *Sus* in the absence of the supra-trochlear foramen; the trochlear surface has the ridge on the radial half more prominent than in either of the allied genera; the ulnar condyle is more prominent than in *Hippopotamus.* Width of proximal extremity 3·5 inches; width of distal extremity 2·3 inches. The shape of the distal extremity is like that of the humerus of *Anthracotherium*, but the supra-trochlear fossa is deeper.

Radius and ulna.—The radius and ulna resemble those of the *Pig*, and differ from those of the *Hippopotamus* in being quite free throughout their entire length. The radius is a twisted bone with a triangular shaft; it is flatter than in the *Pig*, and is broader at the proximal and narrower at the distal extremity, so that the latter is the widest of the two surfaces; whereas the reverse is the case in the *Pig*: the bone is not contracted in the middle, as in *Hippopotamus.* The distal extremity of the ulna, on the other hand, is larger than in the *Pig*, and the bone takes a larger share in carrying the carpus: the larger size of this extremity of the ulna is a *Hippopotamine* character. The length of the radius is 7·3 inches, the width of the proximal extremity 1·7 inches, and of the distal extremity 1·05 inches. The greatest length of the distal articular surface of the ulna is 1·2 inches.

Position of genus.—From the above comparisons it will be seen that the osteology of *Merycopotamus*, as far as we know it, is very closely allied to that of *Hippopotamus* and *Sus*, but it presents certain characters different from that of both genera. Beyond a slight resemblance in the form of the teeth and of the astragalus, it does not show affinity to the *Anoplotheres*, among which it is placed by Pictet. I should be inclined to place the genus in the family *Hippopotamidæ*, forming a link between that and the *Anthracotheridæ*; the three genera *Merycopotamus*, *Hyopotamus* and *Anthracotherium* are aberrant forms, connecting the *Suine* to the *Anoplotheridæ* and the *Ruminantia.*

A curious mistake has been made regarding this genus by M.M. Pictet and de Blainville in the *Traité de Palæontologie* (vol. I, p. 322) of the former writer: a lower jaw described by Falconer (*Journal Asiatic Society, Bengal*, vol. VII, p. 1038), under the name of *Hippopotamus dissimilis* is placed under the genus *Hippopotamus*, with the remark—"Je pense que cette espèce est la même que celle qui est figurée dans le *Fauna Antiqua Sivalensis*, sous le nom de Tetraprotodon Palæindicus." ! In reality, the jaw should have been placed under the genus *Merycopotamus*, which is also described in the same work (p. 342); before the latter genus was determined, Falconer had referred all the bones belonging to it to *Hippopotamus dissimilis.* M. de Blainville has made a similar error to that of M. Pictet.

ADDENDA AND CORRIGENDA TO PAPER ON TERTIARY MAMMALIA (*ante page* 86) *by* R. LYDEKKER, B.A., *Geological Survey of India.*

HYDASPIDOTHERIUM MEGACEPHALUM, nov. gen. nobis.—The cranium from the Siwaliks referred to in the last number of the Records under the name of *Bramatherium*, has now been cleaned from matrix, and turns out to belong to a new genus of *Sivatheridæ*, for which I propose the name *Hydaspidotherium*, from the classical name of the river Jhelum, near which it was found. The distinctive characters of the cranium are the possession of one common horn-base on the vertex, and the absence of anterior horns; the profile is concave, the orbit depressed, and separated by a long interval from the horn-core; the teeth resemble those of *Bramatherium*. A figure and full description will subsequently appear.

The genus *Ursitaxus* (Hodgson's synonym for *Mellivora*) should be removed from the lists of extinct genera, p. 95, and added to the lists of genera common to the Indian Tertiaries, and to the living faunæ of India and Africa. The genus *Sanitherium*—H. von Meyer—(*Sus pusillus*, Falc.) should be added under *Artiodactyla* to the lists from which *Ursitaxus* is removed.

OCCURRENCE OF PLESIOSAURUS IN INDIA, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

The discovery of the remains of this genus in the Oolite of Kachh is the first instance recorded of its occurrence in India. The specimen on which this determination is founded is a portion of the distal extremity of a mandible; it was discovered by Mr. Wynne at Burrooria in Kachh, in the Umia (Tithonian and Portlandian) beds; it comprises the whole of the symphysis and small portions of the rami of the mandible; on the right side it contains the alveoli of five teeth, and on the left side of four. The alveoli are completely surrounded by bone; the distal extremity of the symphysis is rounded, its upper surface flat, and pierced by neural foramina, interiorly to the teeth; there is an ovate prominence on the upper surface at the junction of the rami, the inferior surface is rounded and convex, the symphysis being rather longer here than on the upper surface. The dimensions of this specimen are as follows:—

	In.
Length of symphysis on upper surface	2·92
Ditto ditto lower surface	3·55
Width of jaw at union of rami	3·50
Width of jaw at second alveoli	2·61
Thickness of jaw at union of rami	1·95

The specimen agrees almost exactly in form and size with the lower jaw of *Plesiosaurus dolichodeirus* of the English Lias; but it would not be prudent to affirm its identity till further specimens are discovered. The range of the genus in England is from the lower Lias to the lower Cretaceous, so that no inferences can be drawn from this specimen as to the homotaxis of the beds from which it is derived.

NOTES ON THE GEOLOGY OF THE PÍR PANJAL AND NEIGHBOURING DISTRICTS,

BY R. LYDEKKER, B.A., *Geological Survey of India.*

The present paper is in continuation of Mr. Medlicott's paper on the Geology of the Jamú District (*supra*, p. 49); it treats of the inner band of the Sirmúr group,* and the rocks lying between them and the valley of Kashmír. The country lying in this area embraces part of the lower hills formed of the lower tertiary rocks, and the higher mountains composed of older rocks which divide Kashmír from the outer hills. Mr. Drew (*Jamoo and Kashmír Territories*, chaps. i and vi) has divided the mountain systems of the district into the regions of the "outer hills"; and of the "middle mountains;" divisions coinciding very frequently with the geological boundaries.

Notices of the geology of parts of this district have already appeared in various publications, the chief of which are—

Wynne, Records, Geological Survey of India.—Vol. VII, p. 64.
Verchere, J. A. S. B. Vols. XXXV—VI.
Godwin-Austen, G. J, G. S. L., Vol. XXII, p. 29, and Vol. XX, p. 383.

The physical features of that part of the district which is external to the division between the Sirmúr and older rocks are very similar to those which occur in Mr. Medlicott's country. Along the whole of the above boundary the general dip of the Sirmúr rocks is north-east or towards the older rocks—a feature prevalent for hundreds of miles along the Sub-Himalayas; and, except where anticlinals occur, the outer bands of the same rocks have also generally the same dip. The outcrops are usually abrupt and steep, presenting a very characteristic banded appearance: owing to the frequency of the north-east dip, the northern sides of the hills are usually those the most covered with vegetation.

In looking over the country from one of the higher inner passes, such as the Rattan Pír or the Hají Pír, the inliers of the "Great Limestone" of Mr. Medlicott are seen standing up as bold rugged cliffs, towering high above the rocks of the tertiary series, and easily distinguished from them by their "rocky" appearance.

It is, I think, a character very prevalent among the red rocks, that the higher ridges have generally a comparatively flat dip, while the rivers have excavated their valleys along lines where the dip approaches the vertical.

Along the inmost boundary of the Sirmúr group there is a sudden break between these rocks and the inner metamorphic series; the general dip of the former towards the latter group seems to show that this junction as it now exists is faulted. I have never seen any instance where I could distinctly assert that the red rocks had been deposited unconformably against the base of a cliff of metamorphics; and although I have not found any traces of the former overlying the latter beyond the fault, I cannot help thinking that such an extension must originally have been the case to a certain extent, and that the present relationship of the two has been brought about by subsequent up-or-down-thrusts.

In the extreme west of my district the red rocks are bounded by the confused limestones and shales of the nummulitic and oolitic series; owing to the heat of the season, I was not able to proceed up the Kishengunga valley to see the relations of these nummulitic lime-

* I use the term "Sirmúr" as convenient and unambiguous for the whole lower portion of the tertiary series, although it has not been geologically defined in the region under notice, as it is to east of the Ravi. The term "Marí" (Murree) has been more especially applied to the supra-nummulitic zone, the equivalent in the west of the Dugshai, or perhaps the Dugshai and portions of the east. This zone, with the upper part of the Sabathú group, may also be sometimes indicated generally as "the red rocks."

stones to the metamorphic series; but I presume there must be continuation of the main fault between the two groups.

In certain places the lowest exposed beds of the metamorphic series consist of dark-blue limestone passing up into or alternating with shales; in other places the limestone series is not exposed; in the former case there is a great physical break in the country at the Sirmúr metamorphic junction, formed doubtless by the unequal disintegration of the limestone, and red clay and sandstone series; in the latter case the junction between the two formations does not form any marked feature in the country, the rapidity of weathering of the two kinds of rocks being approximately equal.

I do not think that there is any need of adding to the descriptions of the red-rocks given by Mr. Medlicott in his paper above quoted, their composition being exactly similar in my district.

In the lower part of the Marí district (Shaddita) the purple sandstones and red clays of the Sirmúr group rest suddenly upon the nummulitic limestone, without the intervention of the red and green splintery clays of the upper Subathú zone which occur to the eastward; it appears, therefore, that the bottom beds of the red series are unrepresented here: at Marí itself the splintery coloured clays are present, and the junction between the limestones and red series is transitional as in the original Subathú sections; but the great thickness of dark purple slatey shales which occur on the Píne River in the Jamú district (see Medlicott) do not seem to be fully represented here.

The whole of the nummulitic rocks forming parts of the high ranges to the west of Pindí and Marí appear to me from the general similarity of their mineral characters to belong to the Subathú series; and I do not see, in the absence of characteristic groups of fossils, any strong reason for separating these beds, under the name of Hill-Nummulitic Limestone, from the nummulitic limestones of the typical Subathú zone. It is true, however, that the upper limestone bands in the Marí district are frequently of a lighter colour than the lower, but, on the other hand, the shales in both the upper and lower beds are exactly similar in character to those of the typical Subathú zone of Mr. Medlicott: the whole of the nummulitic series in this district is undoubtedly of a much greater thickness than in Jamú; approaching thereby to the nummulitic series of Sindh (Blanford, Rec. Geol. Surv., Ind., *supra*, p. 8), and perhaps indicating a formation deposited in a deeper sea than that of Jamú. The exact or even approximate thickness of the nummulitics in this district, however, is very difficult to determine, since they are so mixed up with the very similar limestones and shales of the oolitic and underlying rocks, that it is almost impossible to divide the two.

In the nummulitics of this district there occur certain bands of thick-bedded dark limestone abounding in nummulitics which do not occur in the Jamú district; it is, I think, a by no means improbable suggestion that part of the purple clay series of the Jamú district (nummuliferous on the Píne River), and which I have said does not seem to be represented here, may really belong to the same horizon as part of the limestone and shale series in this district; the series in the Jamú district having been deposited in a more shallow sea than the present beds.

Mr. Wynne (*sup. cit.*) has described a number of purple sandstones and red clays intercalated between the upper and lower limestone series in the Marí district; these beds, or the greater part of them, are so exactly similar in mineralogical character to the overlying Marí beds, that I cannot but think their occurrence in their present position is due to faulting, though the relations of the different bands are difficult to determine, owing to crushing and talus deposits.

The course of the Jhelum between its bends at Mozaffarabad and U'rí runs either on or near to the line of a broken anticlinal: the beds on the north bank are of a darker colour, and more slaty structure with less sandstone, than those on the south bank, which are like the upper Marí beds; the beds on the north bank approach in character closely to those of the Píne River in Jamú. The Jhelum anticlinal continues its course near the boundary of the red rocks down to Púnch, where it becomes lost among the complicated disturbances and foldings which have there taken place.

From U'rí to a little below Púnch it will be observed on the map that the strike of all the rocks becomes nearly due north and south, returning to its normal line at Rajaorí. The limestone hills to the east of the Hají-Pír are remarkable for their peculiarly even summits. A strong band of buff nummulitic limestone with black shale bands, capped by purple and green splintery shales, runs to the south from the Hají-Pír, dying out to the north-west of Púnch.

A well-marked anticlinal flexure runs through the purple rocks from Rajaorí to the north-west.

A north and south section along the course of the Aus River from Sar to Arnas cuts through the whole of the red series from the metamorphic junction to the Great Limestone at Riassi: the beds throughout this section have the prevailing north-east dip, and appear to be arranged in a series of step-faults; a fault seems to me to occur at the base of each main ridge, the lower beds always consisting of dark purple slatey shales with few sandstones, while the upper beds are composed of the brighter red clays and purple sandstones of the Marí series. I have never seen in any of these sections the coarse (Siwalik?) conglomerate capping the red series as described by Mr. Medlicott above Chineni.

Another large outcrop of the "Great Limestone" has been mapped by me along the north bank of the Chínáb, occurring as usual on a broken anticlinal line. At Shartalla this limestone is nearly vertical with a north-east underlie; it is succeeded suddenly by the red clays and purplish sandstones of the upper Marí series, with nearly the same dip and strike and apparently conformably; to the west of the village of Shartalla, however, the red beds of the spur on which the village stands are seen striking against the broken edges of a high cliff of the limestone, showing the existence of fault with a probably very great downthrow. No traces of the nummulitic series which occur in such force resting upon the Great Limestone at Arnas are seen at Shartalla.

Here I would say a few words as to the probable age of the Great Limestone, upon which, I think, the present inlier throws a little light. This limestone as it occurs at Riassi has been well described by Mr. Medlicott (*sup. cit.*); I may add that when seen from a short distance its general appearance is very massive, and exhibits but slight signs of distinct stratification in its lower beds, although Mr. Medlicott tells me the higher beds are more distinctly stratified.

The base of the limestone outcrop on the north of the Chínáb has precisely the same appearance as the Riassi limestone; but on passing north and coming to the topmost beds of the series at Shartalla, we find a great change in the character of the rock: instead of continuing with the same unstratified massive appearance, it becomes thin-bedded, less cherty in structure, and more blue in colour, with a very characteristic banded or ribboned look. These uppermost beds are exactly similar in character to the carboniferous limestone of Vernag in the Kashmír valley, described by Major Godwin-Austen (*sup. cit.*); and I think the two are very probably of the same age. The only fossil I found in the Shartalla limestone was a portion of a Fenestella, weathered out on the surface of a cliff, but which I was unable to detach; many portions of the Kashmír carboniferous are similarly unfossiliferous.

I will now proceed to describe the main features of the metamorphic rocks along the boundary of the Sirmúr group, taking sections across the strike at a few isolated points. Considerable difficulty must occur in dealing with these rocks, as they have hitherto proved unfossiliferous both to Major Godwin-Austen's and to my own search; I, moreover, have not seen any good instances of the super-position of newer rocks upon them from which an idea of their age could be gathered.

My first section is taken along the gorge of the Jhelum between the villages of Urí and Bárámúlá. The Sirmúr rocks at Urí have a high dip towards the metamorphics; the metamorphics also continue with the same dip within the fault.

Leaving the red rocks of the Sirmúr zone, the first beds we meet with consist of alternations of schists and limestones; the former are either red or green in colour and are frequently magnesian, and soapy to the touch; occasionally some of the green shale bands contain lenticular nodulars of chert; the limestone (some 150 feet in thickness) which at first alternates with, and then succeeds to, these shales, is dark blue in colour, soft and somewhat earthy, and never crystalline; it becomes gradually fissile, and seems eventually to pass up into the overlying slates, but the section is not very clear at this point. After very careful search, I could find no trace of any fossils in this limestone. Mr. Wynne, however, tells me that on the opposite (right) bank of the river he obtained a few very minute spiral Gasteropods. In mineral structure this limestone is totally unlike either the Nummulitic or the Great Limestone.

Both the limestone and its accompanying shales are but very slightly metamorphosed, while they are succeeded by highly metamorphic slates and quartzites, passing in some places into gneiss. It appears to me hardly likely that these underlying slightly-altered beds can really be older than the metamorphics; if this supposition be true, the outer series of the metamorphics must be inverted, which inversion, as I shall show below, must extend along the whole of the Pír Panjal and adjoining range. Mr. Wynne says that the Urí limestone and shale series is very like in mineralogical character to the Triassic beds of Changla-galli and other places in the Hazara district, and is inclined to correlate the two. Dr. Stoliczka also conjectured that these beds were of Triassic age; on these grounds, these and similarly placed beds to the east have been conjecturally classed as Triassic in the map, though a strong objection to this view is noticed further on.

On leaving the limestone north of Urí the flaggy slates continue with slight alterations in mineralogical character along the Jhelum valley into Kashmír; they are very thick and gritty at Urimybo, where they form almost inaccessible perpendicular cliffs along the left bank of the river. They become somewhat crystalline and hornblendic at Naoshera. There are several folds or faults in the section, but the dip is frequently concealed by metamorphic action. None of the so-called amygdaloids occur in this section.

Along the river-bed there occur a great quantity of gneiss boulders, forming terraces above the present river level. Major Godwin-Austen supposes these to have been brought down to the present position by glacier action. The gneiss is not seen *in situ* anywhere along the road section, but occurs in the mountains on both sides. The gneiss is light grey in colour with large porphyritic crystals of white orthoclase.* The gneiss alternates with, and forms an integral part of, the metamorphic slate series, as will be more fully noticed in the Banihal section. Pebbles of the same gneiss are also found in the streams flowing from the Nilkanta Pass, showing that it extends as far west as that point.

* The Buddhist temple near Naoshera is built of this stone, and not of *amygdaloidal trap*, as stated by Dr. Bellew ("*Kashmir and Kashghar*," p. 53).

Mr. Mallet has kindly examined a specimen of this gneiss for me, and says that it is composed of the four following minerals, *viz.*, orthoclase forming the large crystals, frequently twins, of a dead white colour; milk-white quartz; and two species of mica, probably biotite and muscovite. This appears to be the same gneiss as that described by Dr. Stoliczka as containing albite veins.

The limestone band continues to underlie the metamorphic series from Urí to the Suran River, where I have taken another cross section; on the Bitarh River, between these two points, the green amygdaloidal rocks are intercalated with the slate series, a short distance from the limestone.

The section up the course of the Suran River towards the Pír Panjal Pass gives the following series of rocks. Leaving the red rocks of the Sirmúr group at the village of Draba, we come upon a thick band of dark-blue limestone (without polychroic shales) similar to that of Urí; the limestone is rather more altered and slaty than to the west, and is soon succeeded by thick-bedded flaggy shales, and then again by a variety of the peculiar amygdaloidal rocks noticed by Mr. Medlicott (*sup. cit.*, p. 52).

Before noticing these latter rocks, I must refer to a statement of Major Godwin-Austen, asserting the existence of nummulitic limestone on the southern face of the Pír Panjal (G. I., G. S. L., vol. XX, p. 385). The outcrop of limestone noticed above must, I presume, be the limestone referred to, as no other exists on the Pír Panjal. When Major Godwin-Austen speaks of the sandstone as overlying the limestone, he must imply a normal overlie with inversion, for the apparent relations from dip would place the sandstones of the Sirmúr group below the limestones; in reality the two are separated by a fault.

The passage of the limestone into the overlying slates, however, is so clear, that there can be no doubt but that they belong to this series. The only remaining question is—does the limestone contain nummulites? In answer to this, I can only say that after a very careful search I never met with any; and, moreover, Major Godwin-Austen himself makes no mention of having found nummulites in these beds; apparently, he only placed this limestone in the nummulitic group from its apparent association with the red rocks in the same manner as he at first supposed the limestone of the Dal Lake in Kashmír to be nummulitic, which afterwards turned out to be carboniferous. This limestone is serially continuous with that of Urí, in which both Mr. Wynne and myself have carefully hunted for nummulites without success.

Returning now to the so-called "amygdaloidal traps," we find these rocks of very common occurrence all along the Pír Panjal range. They were considered by Dr. Verchere to be of volcanic origin—a supposition which does not appear to me to be borne out by their mode of occurrence; unfortunately, I have mislaid the specimens which I had intended to bring down for examination.

These amygdaloids always occur interstratified with the slates of the metamorphic series, the passage between the one and the other being gradual. They generally also seem to be locally continuous in extent with the slate series,—not thinning out, as should be the case if they were contemporaneous traps; neither are there any beds of trap-ash in the series. There is no sign of any greater alteration in the slate beds which lie below them than in those above them, and the amygdaloids themselves are very distinctly stratified. The base of the rock is either green or purple in colour, and the amygdala either green or white, varying in size from that of a pea to that of a small walnut; they are frequently irregular in shape; the base is very hard and fine grained, and appears to be partly silicious.

In places, as on the Banihal Pass, these rocks pass imperceptibly up or down into almost unaltered earthy sandstones and grits, without amygdala; of these sandstones there can be

no doubt as to their aqueous origin; in other places the amygdaloids pass up into slates. How far the former presence of cavities (now filled by amygdala) in these rocks militates against their metamorphic origin, as indicating the absence of excessive pressure, I leave to more experienced physicists than myself to judge; I have never seen these amygdaloidal rocks in contact with strata of the Sirmúr group, as noticed by Mr. Medlicott on the Raví (*sup. cit.*, p. 52). Whatever view may be held as to their origin, there can be no doubt but that they are contemporaneous with the great mass of rocks of the Pír Panjal. Dr. Stoliczka in his Yarkand Journal (p. 4) considers the similar amygdaloidal rocks of Kashmir as metamorphic.

Continuing our section up the Suran River, we come upon another band of blue earthy limestone at the village of Bifliage, followed by the same series of amygdaloids and slates. This second band of limestone appears to be faulted against the amygdaloids of the outer group, and is probably only a repetition of the same series. The whole of the rocks noticed above have a steady north-easterly dip. The green and purple amygdaloidal series come to an end about a mile below Baramgalla; they are succeeded by silky magnesian shales. Thick bands of white quartzite are here and there interstratified with the shales.

Owing to the great quantity of snow on the pass, I only went along the road as far as the halting place of Poshiana; shales and amygdaloids continue thus far with the same dip; pebbles of the same rocks form the only débris brought down by the streams, so these probably continue all the way up to the pass. The only other rock I noticed in the streams was a very hard silicious conglomerate, containing pebbles of quartzite and slate. I did not see this rock *in situ*; it probably indicates a break somewhere in the slate series. Gneiss does not occur anywhere on the south side of the pass. Between Baramgalla and Rajaorí the same slate and amygdaloid series continues, but the Urí limestone is not exposed at the base.

To the eastward of the Pír Panjal Pass, along the valley of the Aus River, I have not been able to take any section across the strike of the strata for a considerable distance, having merely followed the boundary of the metamorphic rocks. The series of rocks in this region exposed at the base of the slate series differ considerably in character from those to the westward. At the village of Kiol the following series is well exposed along the bank of a tributary stream; the section is from below upwards:—

a.—Purple or white, fine grained, glistening quartzites; base not exposed, and top only seen at intervals.

b.—Black shales (50 to 200 feet thick), containing thin bright bends of brittle coal, and nodules of iron-ore; in many places the shales are altered into hard black

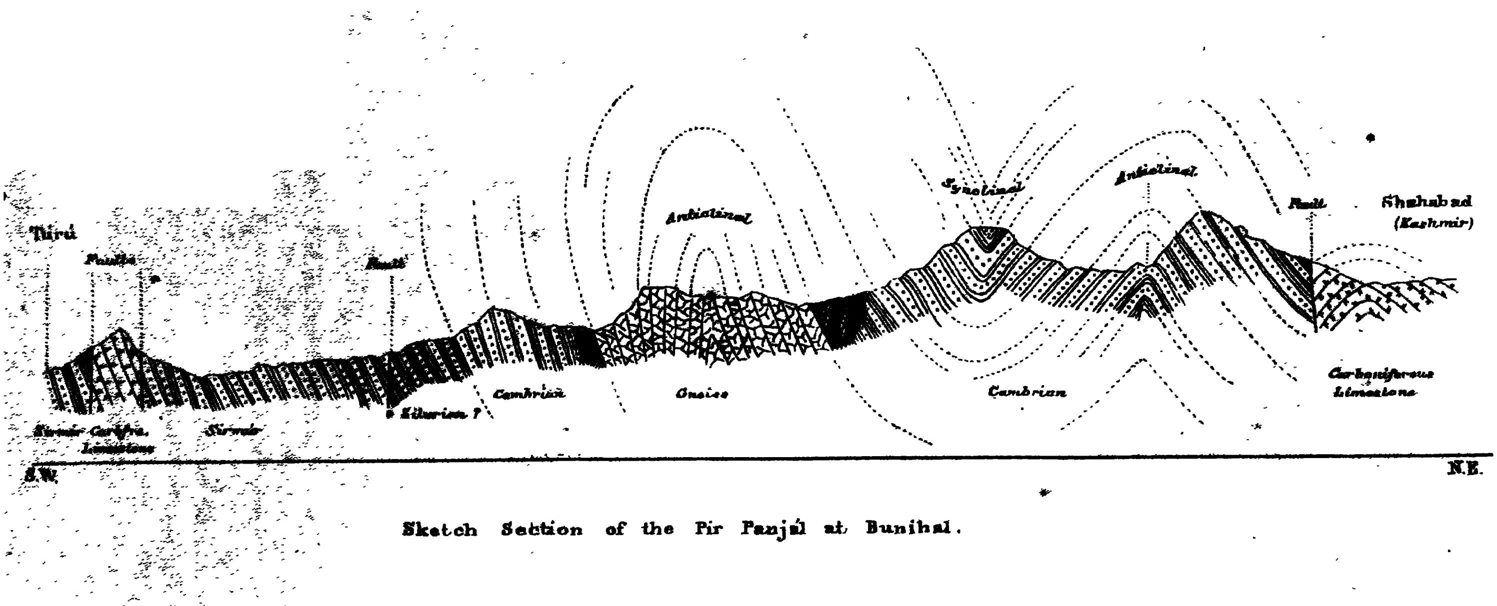
c.—Dark blue earthy limestone, frequently bituminiferous; sometimes massive but more usually nodular, passing gradually up into the next zone.

d.—Amygdaloidal and black slate series.

These I shall subsequently designate as the Kiol group.

The limestones appear to be very similar in mineralogical character to those of Urí, occupying the same relative position under the metamorphic series. The coal shales are not found at Urí, but occupy the position of the green and purple shales of that place. The coal never occurs in layers of more than an inch in thickness, and these do not extend continuously for more than short distances. The occurrence of these slightly altered limestones and coal shales at the base of the metamorphic series, seems to point to the same conclusion as at Urí, *viz.*, inversion, these strata being the newer of the two.

At the village of Sang on the Aus River, the white quartzites of the Kiol series are seen abutting by a faulted junction against the red sandstones and clays of the Sirmúr



Sketch Section of the Pir Panjál at Bunihal.

group, the contrast of the two colours forming a very striking feature, seen for many miles down the valley. The coal-bearing shales of the Kiol group become more altered towards the east; up the valley of the Golabgarh stream porphyritic gneiss similar to that of Urí occurs; the gneiss alternates with the slate series.

The Kiol series corresponds somewhat in mineralogical characters to the Math and Kuling series of Dr. Stoliczka (*Notes on North-Western Himalaya*, Mem. Geol. Surv. Ind., vol. V, p. 185), both alike containing white quartzites, shales, limestones, (altered) sandstones; the Kuling series is, however, of Triassic age, and from their position and from the absence of carboniferous limestone beneath them, I doubt whether the Kiol series could belong to the former period; they seem rather to correspond with the lower beds of Major Godwin-Austen's sections to the north of Pír Panjal, which Dr. Stoliczka conjectured might be of Silurian age. The great mass of metamorphic rocks on the north side of the Pír Panjal may still be considered as of Cambrian age, the Kiol series as probably Silurian, and perhaps partly carboniferous, while the Great Limestone of Mr. Medlicott should be entirely carboniferous. The limestones and shales of Urí correspond in relative position with those of the Kiol series, and may very probably be placed on the same horizon. Mr. Wynne thought the Urí rocks were of Triassic age; but then, as in the case of the Kiol series, there would be no representative of the great carboniferous limestone between the Urí limestones and the metamorphics.

The accompanying diagrammatic section taken from the village of Turu on the east bank of the Aus River into Kashmír, explains my idea of the sequence of the strata. The ridge of central gneiss forms an unsymmetrical anticlinal axis, covered by inverted Cambrian strata on the south, and followed by Cambrian and Silurian strata, much contorted and folded, on the north; beyond the Silurians there is a fault separating them from the carboniferous limestones of Kashmír.

The last section which I have taken extends from the Chínáb River, across the Banihal Pass into Kashmír, and is partly represented in the foregoing diagram. The bright red clays of the Sirmúr series are nearly vertical where they lie against the metamorphics on the Chanz River. Along the north bank of this river the limestones and shales of the Kiol series are not exposed. The rocks seen consist of black and rusty brown slates, generally splitting into irregular flaggy masses, intercalated with frequent beds of quartzite. At the distance of about a mile and a half up the Bichlari stream, we come upon a fine-grained gneiss, sometimes hornblendic and sometimes porphyritic like that of Urí; this gneiss has at first a north-easterly dip of about 60° (inverted), becomes quite vertical at Pantol, and beyond this again requires a north-easterly underlie. The vertical rocks of Pantol form lofty cliffs between which the river flows in a narrow gorge. At both its boundaries the gneiss intercalates with semi-crystalline rocks, and these again with the slate series, so that it becomes almost impossible to define on the map the exact boundaries of the different rocks.

The gneiss does not extend to the northward beyond the village of Gangna, at which place it is succeeded by the overlying series of black and green splinting schists. In places there are a few bends of the green amygdaloids; and a few veins of carbonaceous shale occur in the shaly grits which occur about three miles north of Gangna. A little above Goond there are a few bands of blue earthy limestone, alternating with coarse greyish sandstones and grits, showing but very slight signs of metamorphism. Along the Banihal stream a synclinal and an anticlinal fold run through the grit strata.

On the Banihal Pass these strata contain bands of white and pinkish cherty grits, black flaggy shales, and a few green amygdaloids, all with a steady north-easterly dip; there are also a few bands of a fine-grained grit-conglomerate and strings of white quartzite. These

rocks, as being the uppermost of the metamorphic series, correspond well in position and character with the Bhebeh or Lower Silurian series of Dr. Stoliczka, who suggested (*Notes on Western Himalaya*, p. 350) that part of the metamorphic rocks on this line belonged to the Silurian series.

On the north side of the Banihal Pass there appears (as shown in the section) to be a faulted junction between the metamorphic and the carboniferous limestones of Kashmír (Godwin-Austen, *sup. cit.*); the limestone at the junction dips towards the pass at a high angle in the opposite direction to the dip of the metamorphics.

The gneiss ridge has nearly the same strike as the gneiss of the Dhaoladar range, and the Kiol limestone has the same relative position in regard to the Banihal gniess as the Krol limestone of Mr. Medlicott has to the Dhaoladar gneiss (Medlicott, Mem.) Geol. Surv. Ind., vol. III, map and sect., p. 63); and it is quite possible that the two series are contemporaneous. Dr. Stoliczka has, however, attempted to correlate the Krol limestone with his Kuling (Triassic) series; according to my view, however, the Urí Kiol and Krol limestones are more likely to belong to the Bhabeh or Silurian series, forming an interrupted zone along the base of the Dhaoladar and Pír Panjal ranges for a long distance.

On the low pass at Baramúlá, there occur large masses of modern strata of sand, clay, and very coarse gravel. These beds rise to a height of at least 500 feet above the present level of the river, and are tilted at an angle of about 9° to the eastward; many of the pebbles are crushed *in situ*. These beds are quite different in structure from the Kareewahs of the Kashmír valley, and differ also from the latter in being tilted. As none of the superficial alluvium in the outer hills have been disturbed from their original horizontal position, it is, I think, probable that these Baramúlá beds are older, possibly Siwalik.

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RECORDS

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GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1876. [A

NOTES ON THE AGE OF SOME FOSSIL FLORAS IN INDIA, *by* OTTOKAR FEISTMANTEL, M. D., *Geological Survey of India.**

III, IV AND V.

In the last number of the Records I had occasion to discuss the relations of some local fossil floras of India, and from those relations, after a thorough comparison of our floras with others, I attempted to draw natural conclusions regarding the age of the rocks in which the plants occur. I began with the highest groups of the Gondwána series, and gave a list of fossil plants found in the plant-beds in Kach, and in those interstratified (partly) with the volcanic formations of the Rájmahál hills. I also referred the flora from Golapilli, (Kolapilli) near Ellore (Madras Presidency), to the same age as the Rájmahál group.

Proceeding in natural order, I should next describe the other local floras more or less closely allied to those mentioned above, *i. e*, to the Kach and Rájmahál groups. Such local floras are found in the Jabalpúr group of the Satpúra and South Rewah areas, the Sripermatúr beds near Madras and the Trichinopoly plant-beds. I will, however, postpone the consideration of these for the present, in order to give a preliminary sketch of the floras found in the lower groups of the Gondwána system, which are palæontologically more interesting, as determining the geological range of this system as a whole.

The groups to be noticed in the present paper, according to the classification adopted by the Geological Survey of India, are the following :—

a.—The Panchet group.
b.—The Damúda group.
c.—The Tálchir group.

However opinions may differ as to the age of these three groups, as indicated by their floras, I do not doubt for a moment that all belong to one geological epoch—the Trias. Their precise age, in each case, will be shown by a discussion of each flora separately. I should consider it a great palæontological mistake on my part, and it would show want of knowledge of the literature, were I to decide otherwise, for it seems to me incorrect to suppose that the floras of these groups cannot be compared with a well known fossil flora in Europe, and to refer them instead only to a less perfectly known flora in Australia, with which some of our plant-beds have by accident one or two genera in common. On the other hand, several important genera found in the fossil floras of India are identical with

* Continued from p 43

those described from a well known and defined horizon amongst the rock-systems of Europe, while not one of the animal fossils, which serve to determine the age of the lower portion of the Australian coal strata, has ever been found in our series.

I regret only that the provisional determinations of the plant remains given by Mr. Oldham in his paper in the Memoirs, vol. II, have been misunderstood, and have given rise to wrong conclusions, as the present state of our knowledge shows that the real relations of the fossil plants are different from what they were formerly supposed to be. For any safe inference the following conditions must be fulfilled:—

1.—Only a thorough determination of the fossil remains can be used for the determination of the age of the series.

2.—The comparison must be made with all the known floras, and not only with one, especially if that one be not typical.

3.—Where, besides the fossil plant remains, there are no fossil animals, the typical plants must determine the age of the groups, especially if the species of plants are identical with other well known and characteristic forms found in formations of well determined age.

4.—The conclusions must agree with all laws of Palæontology; if one law is abandoned, the conclusions are uncertain, and contradictions appear which are unnatural.

5.—It is not unnatural that certain genera having a wide range in time should be common to several series. They can, however, be of no important influence in fixing age, which must be determined by the other fossils with which they are associated.

For instance, there is nothing strange in the same species of *Ptilophyllum*, Morr., occurring both in the Rájmahál series (Lias) and in the Kach series (lower Oolite), nor in some species of Ferns or *Equisetaceæ*, being found in the Carboniferous and Permian; and similarly there is no reason why a certain species of the genus *Glossopteris*, Brgt., occurring in our Damúda series, the flora of which is really Mesozoic, should not also be found as well (and perhaps prevail) in some of the supposed Palæozoic coal strata of New South Wales.

We shall see that characteristic species are found in the Panchet group and throughout the Damúda formation, and that these species clearly define the age of the beds, while *Schizoneura* is common to both, and proves that both belong to the same great epoch. The Damúda group has no real connection with the lower coal-beds of New South Wales, although *Glossopteris*, Brgt., occurs in both, and in Australia (but only in the lower strata) is associated with marine fossils of palæozoic age. The plant-beds of Kach and those of Rájmahál, as was shown in the last number of the Records, are, it is true, of different ages, but yet belong to the same great epoch, and are related by the occurrence of certain species of the genus *Ptilophyllum*, Morr.; in the same manner, we shall find that the three series now to be described are also connected together by common forms: that the Panchet group is connected by a species of *Schizoneura* with the Damúda, and these latter again with the Tálchirs by *Gangamopteris*; proving that all these three, though of different age, belong to the same epoch. There may be, and of course are, other opinions about the age of these groups. I can only remark, *that as long as no other proofs are found, the fossils* [illegible] *serve to decide the geological age*, agreeing, as they do, with other well known species from well defined series; and as these are all well known fossil plants, these must decide.

III.—Flora and probable age of the Panchet group.*

In his paper on "the Raniganj coal-field," l. c., Mr. W. T. Blanford described some beds overlying the Damúdas as the Panchet group. From this group, both animal and plant remains are known. The first have been already described by Prof. Huxley in the Palæontologia Indica, Ser. IV, No. I, and determined as bones of *Labyrinthodonts* and *Dicynodonts*. Besides these some *Estheriæ* were also found. These animal fossils, in connection with the plant remains, amongst which Mr. Oldham recognised some triassic forms, led to an approximate determination of the age of the Panchet group. This we find expressed on page 205 of Mr. *Oldham's* paper, l. c. (Mem. III) in the following words: "..... I feel no hesitation in expressing my belief that the Panchet group of the present report represents the earliest portion of the great mesozoic division in the neral geological scale, or, in other words, is of about the same age as the Buntersandstein and Keuper of Europe."

There is only to be remarked, that to this group cannot be attributed the age of two different European strata (as Buntersandstein and Keuper are). From a comparison of the plants I must as I shall show, accept the age of the Keuper for our Panchet group.

Mr. Oldham gave also a provisional list of the plant remains (Mem. III, p. 204) which has been reproduced in a recent paper of Mr. H. F. Blanford.†

The list was—

Schizoneura,	1	species.
Tæniopteris,	1	"
Sphenopteris,	2	"
Neuropteris ?	1	"
Pecopteris,	2	"
Preisleria,	1	"

Of these I have been unable to find any *Sphenopteris* or any true *Neuropteris*, whilst with regard to the doubtful genus *Preisleria*, Presl, we now know from the investigations of Prof. Schenk, that in the specimens which Presl described‡ the leaf fragments belong to *Zamites distans*, Presl, and that the flower or fruit-like figure (fig. 10) is an artificial production, as I will point out hereafter. Our fossils, which Mr. Oldham compared with *Preisleria*, are, as I think, more probably the fructification of some equisetaceous plant.

As I shall before long have occasion to speak of these plant remains, as well as of the others, in more detail, with illustrations of the best of them, I will here only briefly notice the most important—

A—EQUISETACEÆ.

Remains of equisetaceous plants are of frequent occurrence; one very important genus being especially abundant.

Genus : Schizoneura, *Schimp.*

(Schimper et Mougeot : Monogr. d. pl. foss. du Grès bigarré des Vosges, 1844.)

Schimper and Mougeot described this peculiar genus from the "Grès bigarré', (Buntsandstein) of the Vosges-mountains. But it has since been found also in Keuper and in Rhætic. There are in all about four species known.

Vide W. T. Blanford : Memoirs, Geolog. Surv., III, Part I, pp. 29, 126, 182, &c.
" Th. Oldham : Additional remarks on the geological relations, etc. Mem. Geol. Surv. III, p. 197.
Quart. Journ. Geolog. Soc., 1875 : On the age and correlation of the plant-bearing series of India, etc.
Sternberg, II, tab. XXXIII, f. 5—10.

Our species from the Panchet is distinguished from those previously described by the dimensions of the leaflets (on the spathes), which are broader. It comes nearest to *Schizoneura paradoxa*, Schimp.-Moug., from the Vosges sandstone. As I think I am justified in considering this species from the Panchet group as identical with that from the Ràniganj group (Damúda), I shall describe it under the following name:—

1. *Schizoneura Gondwanensis*, Fstm. The description will be given farther on under the Damúda flora.

This species is of great importance; both because it is of influence in the determination of the age (for these broad-leaved forms are only found in the Trias), and because it serves to connect the Panchet with the upper portion of the Damúda (Ràniganj group); as this species is found in both groups of the lower portion of the Gondwána series I name the species *Gondwanensis*. There occur also a great variety of stalks, stems, and evidently als: Rhizomes and rootlets, belonging no doubt to this genus.

The fossils which Mr. Oldham identified with Presl's genus *Preisleria* I am inclined to look upon as the fructification of *Schizoneura*: they have certainly nothing in common with the form described by Presl. I have already mentioned that Presl's figure was taken from a specimen which had been altered by artificial means. Schenk* has proved that Presl's figure† belongs to *Zamites distans*, and he considers that the markings which were taken for inflorescence *were produced by painting the specimen* with Indian ink.‡

B.—FILICES.

Amongst these, there are two species of importance for the determination of the age. The most abundant is—

1. *Pecopteris concinna*, Presl. Sternberg: Fl. d. Vorw. II, Tab. XLI, fig. 3.

A fern, of which we have several specimens found in a greenish grey soft sandy clay which has not been quite suitable for the preservation of the tender parts of the fronds; still our specimens agree exactly with Presl's figure.

Mr. Oldham recognized this species, and says on page 205 of his paper (Mem. III): "A *Pecopteris* is undistinguishable from *P. concinna*, Presl, a triassic (Keuper) form." It is true that Presl and other authors after him considered the locality of *P. concinna*, Presl, (Hoefen near Bamberg) as Keuper, but Schenk has shown that this locality as well as several others belong to the Rhætic formation, intervening between Keuper and Lias. Nevertheless, on account of its occurrence with *Schizoneura Gondwanensis*, Fstm., I will consider it Keuper.

The other species is—

2. *Cyclopteris pachyrachis*, Göppert: Gattungen der foss. Pflanz., Lief. 5, 6, p. 94 Tab. IV, V, figs. 13, 14.

This fossil was originally described from Bamberg, and was supposed to have been found in beds belonging to the Keuper. Other authors, including Schenk, have described it under the same name; but the last named writer, from a special examination of the original, has proved that the locality at which the fossil was procured belongs to the Rhætic beds, and its position is nearly the same as that of *Pecopteris concinna*, Presl.

* ... zur Keuper-und Bone-bed-flora, p. 87.

† ... Sternberg, Vers II, Pl. XXXIII, fig. 10.

‡ ... Grenzschichten-flora, p. 162. "Das Original der fig. 10, in der Kreissammlung zu Bayreuth befind- ... Berücksichtigung, es ist mit Tusche bemalt und sind die runden schwarzen Stellen mit ... Blatt gehört wahrscheinlich ebenfalls zu *Zamites distans*."

Schimper has more lately transferred *Cyclopteris pachyrachis*, Göpp., first to *Neuropteris*, Brgt., and in the last volume of his Paléontologie végétale (III, p. 476,) to *Pecopteris*.

Besides these two very well marked species of ferns there are some more indistinct fragments, only one of which requires notice here. It is a species of *Tæniopteris*, Brgt., which, from the general habit of the frond and its coriaceous appearance, must, I think, be referred to *Oleandridium*, Schimper, and is evidently somewhat allied to *O. stenoneuron*, Schimp, (Schenk) from Rhætic beds.

In general, therefore, the Flora of the Panchet is very poor; but still it is sufficient for comparison with other Floras, and for determining the age, at least with some probability. All the fossil plants hitherto found in the Panchet rocks are from one locality south of Maitúr, on the west branch of the Núnia in the Ráníganj field.

Amongst the Panchet fossil plants *Schizoneura Gondwanensis*, Fstm., is the most important form.

If we now turn to the determination of the age, we have, excluding the reptilian remains, especially to consider three very well marked species, which at once indicate an age lower than Jura (including Lias). Of these three plants, two, *Pecopteris concinna*, Presl, and *Cyclopteris pachyrachis*, Göpp., (as well as, perhaps, the *Tæniopteris*, Brgt.,) would indicate the transition series between Keuper and Lias; but the occurrence of *Schizoneura Gondwanensis*, Fstm., which on the one side is allied to the European broad-leaved species *Schizoneura paradoxa*, Schim.-Moug., from the Vosges (Buntsandstein or grès bigarré), on the other side is the same as the *Schizoneura* so abundant in the Ráníganj group (Upper Damúda), which also, as will be seen, is lower Triassic (grès bigarré), induces me to take the plants altogether as indicating a rather lower age, and I do not hesitate to consider them all as Keuper, a position which is moreover not at all in contradiction with the evidence of the reptilian bones, and with Mr. Oldham's already pronounced opinion (Mem. III). *The Panchet group may be therefore taken as representative of the highest* Trias (Keuper).

I think also the animal remains of this group will not be opposed to these observations, as they agree very closely with many reptilian remains known from the Rhætic of Bayreuth (Verzeichn. der Petref z. Bayreuth; F. Braun, 1840).

This group is allied, through *Schizoneura Gondwanensis*, Fstm., with the Damúdas, in the first place with the Ráníganj group, and through this with the whole formation.

IV.—Flora and probable age of the Damúda Formation.

This formation is largely developed in India; it is also the most important, as it includes the deposits of the so-called "old coal" of India. We find it in Bengal, South Rewah, Sátpúra Range, on the Godávari and in the Eastern Himalaya. I need not mention anything about the stratigraphy of this series, as this has been done in the publications of our Survey.*

* The most important notices are—

Memoirs I.—On the geological structure and relations of the Tálchir Coal-field in the district of Cuttack. (W. T. and H. F. Blanford, and W. Theobald).

Memoirs II.—On the geological structure of the central portion of the Nerbudda District. (J. G. Medlicott).

" " On the geological relations and probable geological age of the rocks in Central India. (by Mr. Oldham).

Memoirs III.—On the geological structure and relations of the Ráníganj Coal-field, Bengal. (W. T. Blanford).

Memoirs VI.—The Bokaro Coal-field. (Th. W. H. Hughes).

" " The Ramgurh Coal-field. (Hughes).

Memoirs VII.—Kurhurbari Coal-field. (Hughes).

Deoghur Coal-field. (Hughes).

It is quite possible and not unnatural that the whole group may be divided stratigraphically and lithologically into the three sub-groups which have been proposed, *viz.*—

Ránigani and Kámthi group	(upper Damúda).
Iron stone shales	(middle do.).
Barákar	(lower do.).

But with reference to their palæontological relations, we must consider all these as belonging to the same age, for the whole of the fossil plants, taken together, exhibit a distinctly limited general character such as is found in a well defined group in Europe. One genus also occurs in the lower coal-strata of Australia, and consequently a corresponding age has been inferred for our coal-bearing rocks, but, I think, incorrectly, for the other plant remains from our Damúda formation which are so very characteristic are not found in Australia, and even the greater part of our species of *Glossopteris*, Brgt., are distinct from the Australian, and also in Australia the same genus occurs in the upper portion of the coal-strata without any fossil animals, but with mesozoic plants, and is most abundant at this horizon. I therefore consider that—

a.—In Australia there may be fossil remains of animals which determine the age of the series, although a certain species of *Glossopteris*, Brgt., is found with them.

b.—In India, on the other hand, as no fossil animals have been found, the age of the series must be determined by the other plants, notwithstanding the occurrence of *Glossopteris*, Brgt.

I look upon the occurrence of *Glossopteris*, Brgt., in the Damúda formation as offering a parallel case to the presence of *Ptilophyllum*, Morr., in the Rájmahál and Kach groups: it is an interesting plant, but without direct influence in enabling us to determine the age of the beds. My conclusions are the following, *that Glossopteris*, Brgt., *began to exist in the lower coal-strata of Australia, where it is said to be associated with fossil animals of carboniferous age, and continued in our Indian coal series, which, however, are characterised by some very well defined genera, which indicate another, and a mesozoic age* as in the upper portion of the Australian strata and in Africa. A more exact determination of the age will result from the comparison of the fossil plants.

It has been, and will perhaps yet be, endeavoured to show that the Indian Damúda series are of palæozoic age, but I do not see where is the proof, as the palæontological results, *the only possible proofs*, indicate *lower mesozoic*, as will appear from the following facts:—

a.—There is no other connection between the Indian rocks and the lower portion of the coal-strata of Australia except the occurrence of *Glossopteris*, Brgt., in both; it is, however, much more developed in India.

b.—The chief evidence that no *Tæniopteris* occurs in the Damúda (Oldham, Memoirs, II, p. 329, and some others), has been shown to be a mistake, as there are found in the upper portion distinct species of broad-leaved *Tæniopteris*, Brgt., with mesozoic characters *(Macrotæniopteris)* Schimp., as I will show more fully further on.

...moirs IX.—Geology of Nágpúr. (W. T. Blanford).
...moirs X.—Sátpúra Coal-basin., (Medlicott).
... XI.—Geology of Darjeeling. (Mallet).
... I will mention only—
... plants from Nágpúr. Quart. Journ., Geolog. Soc. 1861, Vol. XVII, p. 325.
...ons of the Botany, &c., of the Himalayan Mountains. (Plants from Burdwan).
...—Report of the Geological Survey in 1848-49 (Damoodah plants).

c.—The Damúda *Sphenophyllum* (*Trizygia*) proves quite different in habit from those of the carboniferous period.

d.—The discovery of *Voltzia* and *Neuropteris* with single pinnæ (triassic forms) in the Barákars is very important.

e.—In the Barákars there are forms of a genus allied to *Glossopteris* (*Gangamopteris* from the upper portion of the Australian coal-strata), which is almost the only fossil found in the Tálchirs; by it these latter are connected with the former.

Having established these general views, I proceed to discuss the fossil plants, which afford additional evidence in favor of my opinions. I can, of course, only describe the most important fossils. A thorough discussion of all the plant remains will be given in the Palæontologia Indica.

A.—EQUISETACEÆ.

These are very abundant, and one genus is especially important, as bringing the Damúdas into relation with the Panchets, and showing that both belong to the same epoch as a European formation, in which the same genus is well known. This genus is—

a.—SCHIZONEURA, *Schimp. & Moug.*

This genus is especially abundant in the upper portion of the Damúdas. It is found of different sizes, and in various states of development, but everywhere there is only one kind of leaves (spathes), and everywhere they have the same characters. They are very near to those of *Schizoneura paradoxa*, Schimp. & Moug., which they resemble in the mode of connection of the leaflets in two parts of the spathe. Only one specimen is known in which the separation of the leaflets is nearly complete, and this specimen closely resembles Schimper's figure, Pal. Végétale, Pl. XIII, fig. 8. I have no doubt that this specimen belongs to the same species as the others. As I consider that the *Schizoneura* of the Panchets is the same as that in the Damúdas, I will use the same name for both—

Schizoneura Gondwanensis, Fstm.

Diagnosis:

Caule articulato, striato, variabili altitudine ac latitudine; foliis (*foliolis*) 12—22; *plerumque in duas partes vaginæ coalitis; nonnunquam etiam liberis, suberectis, foliolis in duas partes connexis, folia oblongo-ovalia exhibentibus; usque ad* 14·5 *centm. longis, et media parte* 2·5 *centm. latis,* 7—11 *nervos continentibus.*

This diagnosis of this species is, of course, the same for the form from the Panchet group: the habit and the characters are identical in both, only the Panchet forms are in general a little smaller.

As the only difference from the Vosges species *S. paradoxa*, Schimp. and Moug., is in the number of the leaflets, I consider that the two forms are nearly allied, and I look upon our species also as Triassic (Bunter-Sandstein). The fossils described as *Zeugophyllites*, Brgt., from India by Brongniart (Prodrome 121-175) and subsequently by Strzecki (Phys. descr. of New South Wales, &c.) seem to belong also to *Schizoneura*, as well as the fossil described by Mc'Clelland (l. c. Pl. XIV, fig. 4), as *Zamia Burdwanensis*, Mc'Cl.; there is, however, as far as I know the literature, nothing like *Schizoneura* anywhere mentioned as occurring in the lower coal-strata of Australia.

b.—SPHENOPHYLLUM, *Brgt*

In the Damúda formation, both in the upper portion and in the lower, some equisetaceous fossils occur, which were described by Royle as *Trizygia speciosa*, l. c., p. 431. There is no doubt that these fossils belong to the well known genus *Sphenophyllum*, Brgt., and we find them described in Unger's 'Gen. et sp. plant. foss., p. 70, under the name of *Sphenophyllum trizygia*, Ung. Mc'Clelland (l. c., p. 54) described the same form as *Sphenophyllum speciosum*, Mc'Clell., and pointed out quite distinctly that there was no doubt about its being a real *Sphenophyllum*, Brgt. But whilst there is no doubt about the identity of *Sphenophyllum* and *Trizygia*, I prefer Unger's name *Sphenophyllum trizygia*, as there is a constant character in the arrangement of the leaves in three pairs, each of two equal leaves, on one side of the articulation, the lowest pair of leaflets being the shortest, the middle longer, and the highest the longest. There are, therefore, never more than six leaflets, which do not form an entire whorl, but are arranged on one side. This arrangement is quite different from that found in all carboniferous forms, in which the leaflets are all nearly equal and form an entire whorl round the articulation; besides this, the stem of the Indian *Sphenophyllum* is in all cases very thin in relation to the size of the leaves. There can be no doubt about the nature of this species, which must have been a water-plant, expanding its leaflets at the surface of the water.

This *Sphenophyllum* is therefore different from all Carboniferous and Permian forms, and I adopt Unger's name *Sphenophyllum trizygia*, Ung. I have specimens from Burdwan (from the upper portion of the Damúdas, Ránigan j), and from Tálchir near Cuttack from the Barákars. I think there is only one species.

Besides these two well marked fossils, various stalks with articulations, ribs and furrows, are common, and are generally known as *Phyllotheca indica*, Bunb I must say I have seen the real *Phyllotheca* such as Zigno described from the Oolitic formation, and as are known from the upper portion of the coal-strata in Australia (Newcastle), but I am very much inclined to consider a great proportion of the stems found in India as stalks of *Schizoneura*, Schimp.; some others may be indeed internal casts of mesozoic species of *Equisetum*. In Australia there is in the upper portion of the coal-strata also a real *Phyllotheca* in Zigno's sense (Newcastle); the *Phyllotheca* in the lower portion may be *Calamites* or *Equisetum*.

The very doubtful form, called *Vertebraria*, I consider to consist of roots and rootlets (Rhizomes), most probably of some equisetaceous plants, in the same way as the genus *Pinularia*, Lindl. and H., in the carboniferous strata, consists also of rootlets, most likely of *Asterophyllites*, Brgt.

Vertebraria abounds in the Damúdas, and appears to be characteristic of them as a series, but it cannot be quoted for the determination of the age, for which only *Schizoneura Gondwanensis*, Fstm., can be used. As far as I can tell from the literature, and from what I have seen of Australian fossil plants, *Vertebraria* is also known only from the upper portion of the coal-strata.

B—*FILICES.*

In the same way as amongst the *Equisetaceæ*, the genus *Schizoneura*, Schimp. and is the prevailing form, so also amongst the *Filices* one genus is especially prevalent. This, however, cannot be directly employed as evidence of the age of the Damúda;

it is only by its relations to other forms that it can be used as collateral proof. It is only characteristic of the series. This genus is—

a.—GLOSSOPTERIS, *Brgt.*

However interesting this genus may be, it has, I think, been the chief cause of the confusion of opinions about the age of the series in which it occurs—I mean the confusion has been caused by the comparison of this genus with the same in Australia, where it is said to be found in palæozoic rocks. From this evidence also our Indian Damúda groups in which *Glossopteris* is very common have been taken for palæozoic, without considering that *Glossopteris* has in this case been found apart from animal remains which indicate a palæozoic age, but, on the contrary, only with plant remains, which are all mesozoic (Triassic).

I should consider it a great palæontological mistake if I were to take a series in which the majority of the plants are of mesozoic age, and identical or closely allied with well known mesozoic (Triassic) genera and species, to be of any other age than mesozoic, only because one genus is also found in it which is also known from a portion of the coal-strata in Australia. Nobody will class the Permian and Carboniferous as identical, although some species of plants or animals may occur in both.

We should rather say, some species of *Glossopteris* are found in the supposed palæozoic coal-strata of Australia, but the genus also occurs in great abundance in the lower mesozoic coal-strata of India.*

It is only remarkable that, while in Australia there are both fossil animals and plants of lower carboniferous age, of which the latter belong for the most part to genera identical with those found in Europe, there should be in the upper carboniferous (without fossil animals) a sudden change in the flora and no true carboniferous plant found.

But another locality is known for *Glossopteris*, Brgt.; this is in the Karoo beds of South Africa, described by Mr. Tate,† which series that author also puts in the Trias, and I think with justice. This would agree well with our series. Tate recognized in Africa the same forms which are most common here in India.‡

* See a similar opinion by Mr. Dawkins in the transactions of the Manchester Geological Society, Vol. XIV, Session 1875-76, Part II, p. 28: Age of the New South Wales coal-beds. The manner in which Mr. Dawkins expressed himself is quite correct and natural, but I never before read anything about the association of the *Glossopteris* in Australia with *Lepidodendron, Sigillaria, Calamites, etc.*, these being only found below the lower marine beds.

† Quart. Journ. Geolog. Soc., 1867, p. 140 ff.

‡ I cannot discuss this subject further here, and I think it sufficient to quote the following literature about *Glossopteris*:—

Brongniart: Histoire des végétaux fossiles, 1818.
Göppert: Systema filicum fossilium, 1836.
Mc'Coy: On the fossil botany and zoology of the rocks associated with the coal of Australia. Annals of Natural History, Vol. XX, ser. 2.
Bunbury: Fossil plants from Nágpúr. Quart. Journ. Vol. XVII.
Mc'Clelland: Report, 1848-49; Calcutta, 1850.
Dana: Geology (United States Exploring Expedition), 1849.
Tate: South African fossils. Quart. Journ., 1867 (Vol. XXIII).
McCoy: Prodromus of Palæont. of Victoria, II Decade.
Schimper: Traité de Palæontolog. végétale.
W. B. Clarke: Remarks on the sedimentary formations of New South Wales, 1878.
Also all the publications in our Memoirs which I quoted before should here be repeated, especially Mr. Oldham's paper on the probable age of the rocks in Bengal and Central India (Vol. II).

The best known species of *Glossopteris*, Brgt., is *Glossopteris Browniana*, Brgt., of which Brongniart distinguished two varieties: (*a*), *Indica*, and (*b*), *Australasiaca*, which, however, have been described by Schimper as two different species, and I think correctly. I may add that in India the only prevailing form is that with longer and pointed leaves and much narrower reticulation, *Glossopteris indica*, Schimp., while the generally smaller form with a more obtuse apex and wider reticulation, *Gloss. Browniana*, Brgt., is much rarer in our strata, although it prevails in Australia, where it is the only species found in the lower portion with the marine fauna.

I am now preparing a monograph of the genus *Glossopteris*, Brgt., and some allied genera, in which I will enter more fully into details, and it will be seen that the pointed leaves prevail in the Damúda, and also that of the figures of our Indian forms those in Bunbury's paper (l. c.) are the best, whilst those in Brongniart and Göppert are not very correct.

Brongniart described one form as *Glossopt. angustifolia* from Ráníganj; I have not found any specimen from India, but I have seen one from Australia, from the upper portion of the coal-strata.

Besides these I have been able to distinguish a great many species, or at least varieties, also young fronds, etc.

Near Nágpúr several specimens have been found with fructification, with 1—4 rows of sporangia between the stalk and the margin, which, together with the reticulate nervation, tend to indicate a relationship between *Glossopteris* and some living species of *Polypodium*. On one specimen of the Australian *Glossopteris*, Brgt., Mr. Carruthers seems to have observed a different fructification, consisting of linear sori along the veins, but nearer to the margin of the leaf. (See Carruthers in Daintree's paper on the Geology of Queensland. Quart. Jour., Geol. Soc., 1872). This would prove further the difference between our *Glossopteris* and the Australian species.

The best known forms are therefore—

1. *Glossopteris indica*, Schimp.—large pointed leaves, narrow reticulation. Sori in rows on the surface of the frond.—Prevailing in India.
2. *Glossopteris Browniana*, Brgt., Schimp.—smaller obtuse leaves, wider reticulation. Australian form; the only species found in the lower strata.
3. *Glossopteris angustifolia*, Brgt.—different in the nervation, known from the Damúdas and the upper portion of the coal-strata in Australia.

Other species will be shewn to exist after the special examination of this genus.

There are, besides these, several species described by Bunbury and Mc'Clelland, but Mc'Clelland's figures (l. c.) cannot be recognized, as they are not accurately drawn. I need only mention *Glossopteris acaulis*, Mc'Clell., Tab. XIV, f. 3, 3*a*, which is not sufficiently well figured to be identified, and others are equally imperfect.

The figures of Australian species of *Glossopteris*, Brgt., in Dana's Geology are also of no use for comparison, as the reticulation is incorrectly and irregularly represented.

Glossopteris is the most common and characteristic fossil of the Damúdas. It is [illegible] in all three sub-divisions and is the unfailing evidence of the occurrence of this

Bunbury's *Glossopteris musæfolia* seems from the drawing rather to belong to *Tæniopteris*, Brgt., although the author says that the veins anastomose near the stalk. This the figure, however, does not exhibit at all, and the same may be said of *Glossopteris stricta*, Bunb., from Kámthi. Tate's *Dictyopteris simplex*, (l. c.) Pl. VI, fig. 6, is a *Glossopteris* of the same group to which some of our Indian species also belong.

In one way *Glossopteris*, Brgt., may be considered evidence of a mesozoic age: if it is compared with other ferns with reticulated leaves, the most nearly allied is the Triassic and Rhætic *Sagenopteris*, Brgt., and some forms of *Glossopteris* are evidently related to this Triassic genus.

b. GANGAMOPTERIS, *Mc'Coy.*

In the lower group of the Damúdas (Barákars) there occur some ferns resembling *Glossopteris*, which, however, on a closer examination, show different characters; the most prominent of these is the want of the distinct midrib, which is found in the real *Glossopteris*, Brgt.; there are instead of it only three or four thicker veins starting from the base; the other veins radiating from the base towards the margin. This is a character which we find partly in *Cyclopteris*, but while in the latter genus the veins between their point of origin and the margin are divided only dichotomously, in this form from the Barákars they are reticulated, as in *Glossopteris*, Brgt. We have therefore in these leaves—

1.—Want of a distinct midrib.

2.—A venation radiating from the base towards the margin, as in *Cyclopteris*, but yet reticulated, as in *Glossopteris*.

3.—A rounder leaf than in *Glossopteris*. Similar forms have been described by Mc'Coy (Palæontol. of Victoria, Dec. II) from Australia as *Gangamopteris*, and I think I am not wrong in putting these forms from the Barákar group in the same genus.

The species I will call—

Gangamopteris Cyclopteroides, Fstm.

As this species occurs also in the Tálchir group, where it is almost the only fossil, I will give a diagnosis and a fuller discussion when treating of that group. A similar form* is described by Mr. Tate from the Karoo beds (Triassic) in South Africa as *Cyclopteris Jenkinsiana*, which, I think, also belongs to this genus.

The occurrence of this genus in the Barákars is very important, not for the determination of the age, but because of the connexion it shows between the lower Damúdas and the Tálchirs. It thus unites the latter with the whole Damúda group. These forms have been lately found in the Barákars of the Kurhurbari coal basin. I have also one or two fragments from Kámthi which belong to the same species.

c. SAGENOPTERIS, *Brgt.*

If we take *Glossopteris*, Brgt., as a single-leaved genus, with a certain venation, some other forms with several leaves coming out from the same stalk and a different venation must be separated from this genus and placed with *Sagenopteris*, Brgt. This is especially the case with the *Glossopteris acaulis*, Mc'Clell. (Rep. XIV, fig. 3), which, however,

* See Tate l. c. p. 146, Tab. VI, fig. 4.

is not correctly drawn in Mc'Clelland's Report. I have had the opportunity of seeing in our collections the original specimen and another, and have had both drawn from nature. They exhibit a very different appearance from McClelland's figure: about eight leaves pass out from a common stalk; the middle leaves seem to have been the longest; the venation is peculiar and different from that of our forms of *Glossopteris*, Brgt. I have no doubt these specimens belong to *Sagenopteris*, Brgt.; but the specific name is inappropriate, and should, I think, be changed.

d. TÆNIOPTERIS, *Brgt.*

The absence of *Tæniopteris*, Brgt., in the D a m ú d a group has been urged as one of the principal distinctions between that group and the R á j m a h á l, and a strong confirmation of the p a l æ o z o i c age of the former. This view, however, is no longer tenable, for *Glossopteris danæoides*, Royl., figured by Royle in his work (l. c. Pl. 2-9), is really a *Tæniopteris*, Brgt. The original specimen was from the B u r d w a n coal-formation, that is, from the R á n i g a n j coal-field. I have not seen the specimen, but I have no doubt about the fossil being *Tæniopteris;* the venation proves it, as the veins are distinctly quite free at their base, and only dichotomous in their whole length.

The specimen from the B u r d w a n (Ránigani) coal-field represented by Mc'Clelland in his Geological Report, Pl. XV, figs 13*a*, 16, under the name of *Tæniopteris danæoides*, Mc'Clelland, is of course also a true *Tæniopteris*, Brgt., and judging from the form of the frond and the distance between the veins, I am inclined to consider it the same as the species figured by Royle. In its broad leaves and distant venation this species presents a habit corresponding with that of triassic forms of the genus. There is another specimen in the collection of the Geological Survey from the D a m ú d a formation of B u r g o in the R á j m a h á l hills which leads to the same conclusions as Royle's and Mc'Clelland's figures. Accidentally on the opposite side of this specimen are some fronds of *Glossopteris*, Brgt., thus proving the association of the two genera in the D a m ú d a rocks.

Lastly, I have seen a broad-leaved true *Tæniopteris*, Brgt., from K á m t h i, with very narrow veins, which resembles strongly Bunbury's *Glossopteris musæfolia*, except that the veins do not anastomose near their base (l. c. Pl. VIII, fig. 6), so that I will describe it under a different specific name. Besides this I think that *Glossopteris stricta*, Bunb. (l. c. Pl. IX, fig. 5) is also near to *Tæniopteris*, Brgt., and Sir C. Bunbury himself has figured a fragment of a *Tæniopteris* (l. c. Pl. X, fig. 2) as *Tæniopteris danæoides* (?) Mc'Cl. He may be right. It may therefore be stated without hesitation that together with *Glossopteris*, Brgt., there occur broad-leaved species of *Tæniopteris*, Brgt., with a mesozoic habitus, and that the latter, afford additional evidence against the palæozoic age of the Damúda Flora.

e. NEUROPTERIS, *Brgt.*

When Prof. Schimper described the fossil plants from the Vosges sandstone, he referred to the genus *Neuropteris*, Brgt., some forms which did not quite agree with the c a r b o n i f e r o u s species, although the nervature of the leaflets in these t r i a s s i c forms is the same as in those from the c a r b o n i f e r o u s strata, the leaves of the former being, however, simply pinnate. Not wishing to establish a new genus, he divided the genus *Neuropteris* into two principal groups, of which one, the c a r b o n i f e r o u s type, includes species with bi- or multi-pinnate fronds; the other or t r i a s s i c type comprises the forms with simply pinnate fronds which are found in the Grès bigarré (Bunter.)*

* [illegible] Schimper and Mougeot, Monogr, des plantes fossiles du gres bigarré des Vosges, 1844, p 76

On his Plates (l. c.) XXXVI &c. several species are figured, of which *Neuropteris grandifolia* (XXXVI, f. 1) is the largest. From the Kurhurbári coal-field our Museum received some time since a splendid specimen of the shale accompanying the coal seams. This specimen exhibited three very important genera and species, some of them represented by several specimens. One I have already mentioned, *Gangamopteris cyclopteroides*, Fstm.; another belongs to the genus now under discussion, *Neuropteris*, Brgt.

When I saw the specimen, I at once recognized several fronds of a well developed fern with single pinnæ, one being complete. At first I was astonished to see such a form; but soon I saw another fossil on the same specimen, *Voltzia*, Brgt., which left me no longer in doubt about the simply pinnate leaves.* From the nervature of the leaflets and from the singly pinnate nature of the whole frond, I was sure that the specimens represented a *Neuropteris*, belonging to the group found in the Grès bigarré by Schimper, or, in short, that the specimens represent a lower triassic (Buntsandstein) *Neuropteris*, Brgt. As no palæozoic species of this character is known, I could not longer be in doubt about this, as the occurrence of the genus already mentioned (*Schizoneura*, Schimp. and Moug., also a triassic genus) and of *Voltzia*, Brgt., strongly supported my views. The nearest ally of our specimen appears to be *Neuropteris grandifolia*, Schimp. and Moug., but the Indian fern differs in the following particulars :—

a.—The leaflets in our specimen are wider apart.

b.—They begin, it is true, with entire or only slightly lobate leaflets, but the upper leaflets become larger and deeply lobate or pinnatifid.

The strong stalk both forms have in common. Our plant seems still larger than that figured by Schimper. The simply pinnate character is well seen, the lowest leaflets are nearly entire and small, the middle are the largest and nearly pinnatifid, and the uppermost again like the lower. I will call this fern—

Neuropteris valida, Fstm.

Fronde simplici (pinnata), rhachide valida, striata; pinnulis imis minimis, oblongis, tota fere basi adnatis, margine sinuosis, mediis magnis, lobatis aut pinnatis, media parte basis pedicello latiusculo brevi adnatis, summis imos adæquantibus; nervis creberrimis, nervo primario basilari, vix distincto, secundariis e basi radiatim ascendentibus, dichotomis.

Further description and discussion may be reserved until I can figure this very interesting species, which affords a strong evidence of the triassic age of the Damúda, and, as it happens, of the lower portion (Barákars).

f.—ACTINOPTERIS, *Schenk.*

I had already occasion, when discussing the Kach fossil flora, to mention this peculiar fossil plant, which formerly was united with *Cyclopteris*, Brgt., Professor Göppert having described the only known species as *Cyclopteris peltata*, Göpp. On account of its relation with some living ferns, Schenk called it *Actinopteris peltata*, and showed that the horizon at which it was found was Rhætic. I found similar forms amongst the Kach fossil plants. Schimper, however, had some doubts about the nature of these fossils, and was disposed to consider them merely infiltrations of hydrated peroxide of iron. From the Rániganj coalfield we have a very well preserved specimen of a real fern, which I cannot refer to any other genus than *Actinopteris*.

I call this species—

Actinopteris Bengalensis, Fstm.

Fronde orbiculariter ovata, peltata, ex foliolis singulis, segmenta formantibus composita; foliolis e media parte radiantibus, dichotome partitis, marginem versus latioribus, apice rotundatis; loco insertionis petioli medio.

The whole frond is rather large, circularly ovate in outline, and the leaflets radiate towards the margin from the insertion of the stalk; they are very well marked by a thin layer of coal, and are dichotomous in the same way as in *Actinopteris radiata*, Link. Not a moment's doubt can exist as to this specimen being a fern.

It seems to me different from those from Rhætic strata, but is another proof of the mesozoic character of our flora. From the upper coal measures in Australia there is mentioned also "a peculiar peltate leaf," which may, perhaps, be also an *Actinopteris*, Schenk. (See Mines and Mineral Statistics of New South Wales, by John Lucas, etc., 1875, p. 129.)

Besides the ferns already mentioned, some other forms occur, which, however, need not be noticed here, as they are not of any greater importance than those I have already described. I may, however, add that *Pecopteris Lindleyana.*, Royle, which has been noticed in relation with *Pecopteris australis*, Morr. (from Tasmania), belongs undoubtedly to the group of *Alethopteris Whitbyensis*, Gopp, which seems to include only mesozoic forms;[1] still another *Pecopteris* (*Alethopteris*, Gopp.) is not uncommon, but this also exhibits a mesozoic habitus. Amongst the ferns we have therefore to note especially the following species:—

Glossopteris indica, Schimp., for the series.

Gangamopteris cyclopteroides, Fstm., for the relation of the Damúdas with the Tálchirs.

Tæniopteris danæoides, Mc'Clell. (Royle), and the other broad-leaved species of *Tæniopteris* from Kámthi for the mesozoic age of the Damúdas.

Neuropteris valida, Fstm., for the triassic (Buntsandstein) age of the Damúdas.

Actinopteris Bengalensis, Fstm., mesozoic form.

C.—CONIFERÆ.

Coniferæ are very rare in the Damúdas, but a very important genus has lately been found in the Kurhurbárí coal-fields.

a.—Voltzia.

This genus is peculiar and limited to the middle and lower Trias as Schimper states.* Brongniart, the founder of this genus, was very well acquainted with it, and described four species, all from the Grès bigarré.

On the large specimen from Kurhurbárí, which I mentioned before when describing *Neuropteris valida*, Fstm., there are some branches of a coniferous plant, which, judging by

[1] See Schimper: Palæontologie végétale, II, p. 240.

the form of the leaves, can only belong to the genus *Voltzia*, Brgt. Our specimen agrees best with the following :—

Voltzia acutifolia Brgt.

1838. Brongniart : Prodromus, pp. 108, 190.
1844. Schimper et Mougeot : Monographie, etc., p. 29, Tab. XV.
1871-72. Schimper : Palæontologie végét, p. 241, Vol. II.

When I compare our species with *V. acutifolia*, Brgt., I must also add that the leaves, especially towards the end of the branches, are a little longer and broader. *Voltz. acutifolia*, Brgt., is, with *Voltz. heterophylla*, Brgt., most characteristic of the Grès Bigarré.

Besides this distinct *Voltzia* there is also a branch, with much longer and broader leaves, which I cannot identify with any known *Voltzia*, but rather with *Albertia speciosa*, Schimp. (see Schimper and Mougeot, l. c. Pl. V, f. B), which is also a well known species characteristic of Lower Trias.

This is all that need now be said about the *Coniferæ*.

The above are the most important plant remains from the Damúdas, so far as they have hitherto been determined, and no further discussion is necessary in this paper, as sufficient evidence has been brought forward for the determination of the age.

From the previous discussions I have been led to the following results :—

a.—*Schizoneura* is represented by the same species (*Schizoneura Gondwanensis*, Fstm.), in the Panchet group and in the Damúdas, especially in the Upper Damúdas, or Rániganj, proving that both belong to the same general epoch.

b.—The occurrence of *Glossopteris*, Brgt., in all the three sub-divisions of the Damúdas, besides the occurrence of triassic species (of the age of the Grès bigarré) in both the Upper and Lower Damúdas, proves that all three sub-divisions belong to the same age.

c.—The species *Gangamopteris cyclopteroides*, Fstm., which occurs in the Lower Damúdas (Barákars of the Kurhurbárí coal-field), and which is the prevailing fossil again in the Tálchirs, brings the latter into relation with the former, as I shall show presently.

d.—There is no difficulty in determining the age of the Damúdas. We have to regard only the most important fossils, *viz.* :—

Schizoneura Gondwanensis, Fstm. (a triassic form) ;
Sagenopteris (*acaulis* ?) Mesozoic.
Neuropteris valida, Fstm. (a triassic form) ;
Actinopteris Bengalensis, Fstm., Mesozoic.
Voltzia acutifolia, Brgt. (Grès bigarré) ;
and perhaps *Albertia speciosa*, Schimp. (Grès bigarré).

All these [illegible] closely allied, and some are identical with species which hitherto are known only from [illegible]r triassic; no form is palæozoic, except *Sphenophyllum*, Brgt., which, howe[illegible] very different characters from those of species from palæozoic rocks, the[illegible]g all that I have said and determined, we are obliged, following the gen[illegible]dopted palæontological laws, to consider our Damúda formation as of lower triassic age. Considering the relations of the Damúda beds and the coal-strata in Australia, only the upper portion of the latter present some analogy with these Damúda

beds. In this upper portion (upper coal measures) of Australia we find fossil plants, mostly of mesozoic type, *e. g., Phyllotheca australis, Phyll. Hookeri* (in the New-castle coal-field, belonging to the real *Phyllotheca* type), *Vertebraria* (Damúda type), *Glossopteris* (some of them related with our Indian forms), *Tæniopteris,* broad with narrow-veins, (*Macrotæniopteris,* Schimp.), *Thinnfeldia*-like ferns, *Pecopteris odontopteroides,* Morr., a peculiar peltate leaf (which may possibly be *Actinopteris,* Schimp.), seed vessels of *Conifers* (these may, perhaps, be allied to *Araucarites Phillipsi,* Carr., or *Araucar. Kachensis,* Fstm. ?), and others, without any marine fauna. The lower portion of these Australian coal-strata presents no analogy with our Damúdas, as the latter contain none of the marine animal fossils so frequent in the lower coal-mesaures of Australia.

V.—Fossil Flora of the Talchirs.

This is the poorest flora of all. Only a few fronds have been found, and but one or two localities are known at which fossils occur. These fossils were mentioned by Mr. Oldham* as "a large *Cyclopteris*-like leaf;" Mr. W. T. Blanford had previously recognized the nature of this fossil, and in his paper on the Ránigan j coal-field, Mem., Vol. III, p. 38, writing about the fossils from the Tálchir group, he said, "the best marked was a form intermediate between *Glossopteris* and *Cyclopteris.*"

I noticed above similar fronds amongst the Damúda fossils from the Barákars. I pointed out that there are leaves with a radiating distribution of the veins, as in *Cyclopteris,* Brgt., but the veins are reticulated, as in *Glossopteris,* Brgt., and I referred them to the new genus *Gangamopteris,* Mc'Coy. I also said that these specimens from the Barákars are identical with those found in the Tálchirs: the species I called—

I.—*Gangamopteris cyclopteroides,* Fstm.

Diagnosis:

Fronde oblongo-ovali, subobliqua, integerrima; rhachide nulla; nervis omnibus e basi radiantibus veluti in Cyclopteride, *retia formantibus* (Glossopteridis *similibus*), *mediis ima parte distinctissimis.*

This diagnosis serves for the species both from the Barákars and Tálchirs.

By itself this species does not prove much; but its occurrence both in the Damúdas and Tálchirs makes it at least very probable that these two groups are very near in age, and I, for my part, look upon the Tálchirs as a lower group of the whole Damúda formation, or, in other words, as a lower horizon of the lower triassic age.

Compared with the Australian species of *Gangamopteris,* our species is most nearly related to *Gangamopteris obliqua,* Mc'Coy.†

I have thus given a short outline of the most important fossils from the lower groups of the Gondwána Series, from the Panchets, the Damúdas, and the Tálchirs, and the following general results may be deduced:—

a.—From the relations of the fossil plants of these three grou[redacted]llows that they all belong to one epoch, the triassic.

* Mem. II, p. 335.

† Prodromus of the Palæontology of Victoria, Decade II, Pl. XII, figs. 2, 3, 4.

b.—The Panchet group has *Schizoneura Gondwanensis*, Fstm., common with the Damúdas, and whilst the other two species of the Panchets, *Pecopteris concinna*, Presl, and *Cyclopteris pachyrhachis*, Göpp., would indicate a Rhætic age, *Schizoneura Gondwanensis*, Fstm., tends to give them an older aspect, so that I class them as Keuper.

c.—The Damúdas have yielded important fossil plants of lower triassic age (Buntsandstein). I therefore refer all the three sub-divisions to this age, as the same fossil plants, and especially the same species of *Glossopteris*, Brgt., are found in all three.

d.—The Tálchirs contain a fossil plant, which has been found also in the *Barákars*, *viz.*, *Gangamopteris cyclopteroides*, Fstm., so that I do not hesitate to consider the *Tálchirs* as the lower continuation of the *Damúdas*.

We have derived, therefore, from the plants the following scheme:—

I.—JURASSIC.

Middle.	*Lower.*
Kach.	Rájmahál.
Jabalpúr.	Golapili (near Ellore).
	Sripermatúr (Madras).

II.—TRIASSIC.

Upper (Keuper).	*Lower* (Buntsandstein).
Panchet group.	Damúdas—
	Upper (Kámthi, Rániganj).
	Middle (Iron shales).
	Lower (Barákar).
	Tálchirs.

NOTE ON THE GEOLOGICAL AGE OF CERTAIN GROUPS COMPRISED IN THE GONDWÁNA SERIES OF INDIA, AND ON THE EVIDENCE THEY AFFORD OF DISTINCT ZOOLOGICAL AND BOTANICAL TERRESTRIAL REGIONS IN ANCIENT EPOCHS. *By* W. T. BLANFORD, A. R. S. M., F. R. S., &c., *Geological Survey of India.*

In the preceding paper and in that published in the last number of the Records (*ante* pp. 28—42), Dr. Feistmantel has stated at length the conclusions as to the age of the different members of the great plant-bearing or Gondwána Series of India, to which a careful and exhaustive study of the fossil flora has guided him. How urgently a careful study of the plants was needed it is unnecessary to point out, and the results to Indian Geology must be most important. Guided by the abundance of particular forms, Indian Geologists had hitherto not unreasonably supposed that the Kachh (Cutch) plant-bearing beds were of the same age as those of Rájmehál, Trichinopoly, &c., for in all these localities the commonest species are two forms of *Ptilophyllum* (*Palæozamia*). In the same manner no doubt had ever arisen as to the identity of the Damúda flora with that of the Australian coal rocks, for the common types in both are species of *Glossopteris* and *Vertebraria*, which have hitherto always been supposed to be identical, whilst other forms of *Equisetacea* and ferns from both countries are closely allied. Whether we finally accept Dr. Feistmantel's conclusions, or not, it is impossible to conceive any researches likely to afford a greater service to Indian Geology than the accurate determination of the *homotaxis* of our different fossil floras.

At the same time it will, I think, be advisable to hesitate before accepting as proved the age assigned to the different formations on palæobotanical grounds. Dr. Feistmantel has already noticed (*ante* p. 34) the palæontological contradiction, as he very justly terms it, between the evidence derived from the animal remains in Kachh (Cutch) and that offered by the fossil plants. This contradiction is, however, much greater than would be supposed from Dr. Feistmantel's remark. The matter is so important in its bearing on the relations of Indian rocks that it will be well briefly to recapitulate the history of the examination of the Kachh beds by the Survey.

From a very cursory examination which I made in 1863 of a small portion of the province,* I was led to believe that the plant-bearing beds in Kachh, as a whole, rest upon the series of rocks with marine fossils of jurassic age, but that in some cases marine beds are intercalated with the upper plant-bearing group, and I pointed out that if they are not interstratified, certain fossiliferous bands in the Chárwar range south of Bhooj must have been brought up by a fault. Messrs. Wynne and Fedden surveyed Kachh in 1867-68-69,† the jurassic rocks being chiefly examined by Mr. Wynne, who found that a fault really exists, bringing up the rocks of the Chárwar range; consequently the principal grounds on which my belief in the interstratification of the marine and plant-bearing strata were founded proved untenable. Some information I had received as to the occurrence of marine fossils near Bhooj‡ appears also to have been incorrect. At the same time, the conclusion at which I had arrived, that both marine and fresh-water beds belong to one series, and that the two pass into each other, was entirely confirmed by Mr. Wynne. He also found in some places unquestionable intercalation of the plant-beds with strata containing marine fossils.§

The Cephalopoda collected by Messrs. Wynne and Fedden were examined by Dr. Waagen,|| who found that those from different localities showed the existence of several distinct groups of jurassic strata, ranging from Lower Oolite (Bathonian) to Uppermost Oolite (Portlandian and Tithonian). Dr. Stoliczka went to Kachh in 1872, and spent several months in examining the rocks. He ascertained that four separate groups of jurassic beds, distinguished by well-marked mineralogical and palæontological characters, can be traced throughout the area occupied by the rocks of Oolitic age. These groups he called—

1.	UMIA (Oomia)	Tithonian and Portlandian.
2.	KATROL	Kimmeridge and Upper Oxford.
3.	CHARÍ (Charee)	Lower Oxford and Kelloway (Callovian).
4.	PACHAM (Patchum)	Bath Oolite.

Dr. Stoliczka's names were adopted in Dr. Waagen's account of the Jurassic Cephalopoda of Kachh,¶ and the groups referred to the abovementioned European sub-divisions of the jurassic series.

No account of Dr. Stoliczka's work in Kachh has ever been published. Shortly after returning he left with the mission for Turkestan, and he died on the return journey. The note books used by him in Kachh are amongst the survey records; they contain a very full account of his exploration of the province, and after reading them through, I think there

* Mem. Geol. Surv., India, VI, p. 17.

† Mem. Geol. Surv., India, IX, pp. 1-

‡ Mem. Geol. Surv., India, VI, p. 11.

§ l. c., pp. 51, 210, 213, 215, 218.

|| Rec., Geol. Surv., India, IV, p. 89.

¶ Pal. Indica, Ser. IX, Introduction.

can be no question of the conclusions at which he arrived regarding the relations of the plant-bearing beds to the marine strata. His views were precisely the same as Mr. Wynne's and my own; he determined that the plant-beds form the highest member of the jurassic series, that they pass down into the beds with marine fossils of the Umia group, and that in some places bands of these marine fossils, especially *Trigonia Smeei* and a *Trigonia*, closely allied to the cretaceous *T. tuberculifera** of Southern India, are intercalated in the plant-bearing group. He consequently classed both the plant-bearing beds and the Umia marine beds in one group. Moreover, he found in one place, resting upon the plant-beds, a band containing cretaceous cephalopoda of Upper Neocomian (Aptian) age.† It is difficult to ascertain from Dr. Stoliczka's field notes whether he considered these cretaceous rocks conformable to the Umia beds, or not, but he certainly on his return spoke of this Umia group as of Wealden age.

I may add at once that of the localities mentioned by Dr. Feistmantel, *viz.*, Kukurbit, Trombow, Bhoojooree, Doodaee, Loharia, and Goonaree,‡ all, except the last named, are in the beds forming the upper part of the Umia group, and there is no important difference in the horizon. Goonaree is rather lower in position according to Dr. Stoliczka's map, being in the lower portion of the Umia group and associated with the marine beds, but not one of the localities is below all the beds with upper oolitic fossils. From Nurha,§ the only locality in Kachh belonging to the Katrol group at which remains of plants have been obtained, the specimens, which have just been found, appear to belong to species found also in the Umia group.

It is important to insist upon these facts in order to prevent mistakes. It should be distinctly understood that *the rocks in Kachh (Cutch) with a lower oolitic flora, and containing several species of plants identical with those found in the Lower Oolites of Yorkshire, rest upon marine strata containing Portland and Tithonian Cephalopoda, and are capped by beds with Upper Neocomian (Aptian) Ammonites;* that occasionally the marine strata with upper oolitic fossils are interstratified with the plant-beds; and that the geological position of the Kachh plant-beds has been determined by careful and repeated examination by three different geologists, all of whom agree in their conclusions.

I do not see any probability of error in the determinations of the marine fossils. Dr. Waagen, whose knowledge of Jurassic Cephalopoda is probably equal to that of any Palæontologist living, insists particularly on the remarkable parallelism of the different groups which make up the jurassic series in Europe and India. The remainder of the fauna has not received the same careful examination and comparison as the Cephalopoda, but I believe I am justified in saying that both Dr. Stoliczka and Dr. Waagen considered that the evidence afforded by it coincided with that furnished by the Cephalopodous Mollusca. Dr. Waagen especially states‖ that in the Umia beds of nine species of Cephalopoda,

* Pal. Indica, Ser. VI, 3, p. 815, Pl. XV, figs. 10—12.

† Pal. Indica, Ser. IX, p. 245.

‡ It may be useful to point out where these places are; they are small villages not marked on most maps, and not easy to identify—

Gooneri (Goonaree of map) is in north-western Kachh (Cutch), about six miles east south-east of Lukput.

Thrombow, six miles north-east of Bhooj.

Kukurbit, twenty miles west by a little north of Bhooj.

Bhoojooree, five miles east-south-east of Bhooj.

Doodaee, about thirty miles east of Bhooj.

Loharia, seventeen miles south-east of Bhooj, and south of the Katrol range.

The spelling is that of the map in the Memoirs, Vol. IX.

§ Mem. Geol. Surv., India, IX, p. 213.

‖ Pal. Ind., Ser. IX, Vol. I, Kachh Cephalopoda, pp. 225 and 233.

four are identical with European forms found either in the Tithonian beds of Southern Europe, or the Portland Oolite of England and France, and he adds that this proportion of forms common to the two regions will increase greatly when the other classes of mollusca are described, 'as many of the *Pelecypoda* of this bed seem to be identical with species from the Portland stone,' and elsewhere he especially mentions the abundance of *Trigoniæ* of the type of *T. gibbosa.*

This is not written with a view of impugning Dr. Feistmantel's conclusions. These will be given to the public in full in the 'Palæontologia Indica,' and I have no doubt are as accurate and trustworthy as Dr. Waagen's. But it is important to call attention to the exact terms of the contradiction between the marine and terrestrial forms of the Kachh Oolites, because it shows that one or the other is misleading when applied to the determination of geological age. As the marine fossils are much more numerous, and probably afford a much less imperfect representation of the life of the period, as they occur in a larger sequence of rocks and have attracted much more attention, and as they are preserved in a manner which, I believe, it is generally considered, enables their affinities to be determined with greater accuracy, it will, I think, be admitted by most palæontologists that we must accept the conclusions derived from them. The deduction is inevitable, that the comparison of the remains of plants leads in this case to results, as regards geological age, which are not accurate, and that other identifications on similar data must be received with great caution.

It necessarily follows that although the homotaxis of the Rájmehál flora be liassic, and that of the Panchets and Damúdas triassic, we can only accept this homotaxis as an approximation to the actual geological age of the formations.

Between the Upper Gondwána rocks to which the Rájmeháls and Jabalpúrs belong, and the Lower Gondwána series comprising the Panchets, Damúdas, and Tálchirs, there is a great break in the forms of life. Cycads abound in the former, but have not hitherto been found in the latter, whilst the lower series is characterized by the abundance of equisetaceous plants. The only genera known to be common to the two, are ferns of considerable range in time. It follows as a matter of course that no arguments as to the age of the Lower Gondwána rocks can be drawn from the upper part of the series.

The evidence which Dr. Feistmantel has shown to exist in favour of ascribing a Triassic age to the Panchets, Damúdas, and Tálchirs is undoubtedly of great importance; but I feel some doubts as to whether it is conclusive, and although it is with great hesitation that I venture to express a different opinion on a subject on which Dr. Feistmantel's knowledge of palæobotany enables him to form a more accurate opinion than I can offer, I still think that if the evidence of plants alone be employed to determine the age of the Indian rocks, the relations between the Indian and Australian coal-measures must be taken into consideration in estimating the homotaxis of the Indian formations.*

It is also only fair to point out that the main arguments for the triassic age of the Damúdas are derived from the occurrence of three plants which were only discovered this year. Even admitting, for the sake of argument, that the evidence at present justifies the reference of the Damúda beds to the Trias, it by no means follows that the flora known sixteen years, or even two years ago, was sufficient to warrant the same conclusion, and I believe Dr. Oldham was quite right in 1860,† and that my brother, Mr. H. F. Blanford, was equally justified‡ in 1874, in assigning a palæozoic age to the Damúda formation on the evidence of the plant remains alone. The Panchet beds have always, since they were first defined, been considered as probably Triassic.

* Dr. Feistmantel's argument, that because the marine forms which determine the age of the Australian rocks are absent in India, the evidence of the plant remains becomes of less value, is quite true, but it is just as applicable to the [illegible] plants common to the trias of Europe as to those found also in Australia.

† Mem. Geol. Surv. of India, II, p. 332, &c.

‡ Quart. Journ. Geol. Soc., 1875, pp. 528, 534, &c.

Of course the first and most important question is, whether the age of the Australian coal-measures is definitely settled. It is not surprising that the evidence should be received with some distrust when it is found that ever since they were first described, one group of observers, headed by Professor McCoy, has persistently declared that the coal-beds are of jurassic age, whilst another group, comprising especially the Rev. Mr. Clarke, Professor Jukes, and Mr. Daintree, have contended that they are palæozoic. But there is an important difference between the two classes. The geologists have all examined the rocks *in situ*, and have ascertained that the plant-bearing beds are interstratified with marine bands containing *Brachiopoda* and other fossils admitted to be of carboniferous age by all palæontologists. Of the palæo-botanists, McCoy, Morris, deZigno, Carruthers, Schimper, and others, who have contended for the jurassic age of the Australian rocks, not one has ever examined the beds, and their opinions cannot consequently be of any weight, as opposed to the views of the geologists. Mr. Clarke has published two sections of coal-pits,* in which coal-seams and shales with *Glossopteris*, *Phyllotheca*, and *Noeggerathia* (*? Schizoneura*) are shown to have been reached after passing through beds containing *Spirifer*, *Fenestella*, *Conularia*, *Orthoceras*, and other fossils of admitted carboniferous age. Mr. Daintree also has published a section† showing beds with *Productus* and *Spirifer* resting upon coal-seams with *Glossopteris*. Unless the palæo-botanists can prove that Clarke's and Daintree's sections are incorrect, the question must be decided against the mesozoic age of the *Glossopteris* beds.

The succession of formations in the coal-fields of New South Wales is said to be the following ‡:—

1. Wianamatta beds ... } No *Glossopteris* mentioned in the lists of fossils.
2. Hawkesbury beds ... }
3. Upper coal-seams of Newcastle with *Glossopteris*, *Vertebraria*, &c.
4. Lower coal-seams of Newcastle with *Glossopteris*, *Phyllotheca*, *Noeggerathia*, (*? Schizoneura*) &c. With these and above the plant-bearing beds are bands with marine carboniferous fossils.
5. Marine carboniferous rocks.
6. Lower carboniferous or Devonian beds with *Lepidodendron nothum*, Unger, &c.

The Wianamatta and Hawkesbury beds, so far as is known, contain no plants common to any of the Indian rocks. They are now classed as older mesozoic. They are said to be connected with the beds beneath them, No. 3, by the presence of a plant, *Pecopteris odontopteroides*, Morris, in abundance in both, just as the Panchets in India are connected with the upper sub-division of the Damúdas by the occurrence in both of the same species of *Schizoneura*. In the same manner the floras of Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both, although, from specimens which Dr. Feistmantel has showed to me, there appears to be a considerable distinction in the flora. Until the Australian plant remains are subjected to a thorough revision, it will, perhaps, be unwise to consider too much as proved; but so far as the evidence goes, it appears that all the Australian plant-bearing rocks of Australia are connected by species of plants passing in each case from one to the other, precisely as Dr. Feistmantel has shown to be the case with the rocks of the lower Gondwána series in India, and if on the strength of the evidence we are justified in assigning the Panchets, Damúdas, and Tálchirs to the Trias, because the two former contain triassic plants, and the Tálchirs contain one plant, also found in the lower Damúdas,

* Transactions, Royal Society of Victoria, Vol. VI, 1862, and Remarks on the Sedimentary Formations of New South Wales, 3rd edition, 1875, p. 61; see also Quart. Journ. Geol. Soc., XVII, 1861, p. 354.

† Quart. Journ. Geol. Soc., XXVIII, 1872, p. 286.

‡ Quart. Journ. Geol. Soc., XVII, 1861, pp. 358, 360; XXVIII, 1872, pp. 283, 286, 335, &c. Clarke, Sedimentary Formations of New South Wales, pp. 15, &c.

we should equally be obliged to relegate the whole of the Australian coal-measures below the Hawkesbury group to the Carboniferous, because they contain at least one* species of plant throughout, and their lower sub-division is interstratified with beds containing marine carboniferous fossils.

With one or the other of these Australian coal-beds, No. 3 or No. 4 of the preceding section, the following plants of the Damúda groups are common :—

> *Glossopteris*, two or three species identical.
> *Gangamopteris** (the genus only).
> *Vertebraria*, one species identical.
> *Pecopteris* (*Alethopteris*), one species probably identical.
> *Schizoneura (Zeugophyllites.)*

We have thus five genera and four or five species common, without counting the *Equisetaceæ* (*Phyllotheca*, &c.), which appear somewhat doubtful. With the triassic rocks of Europe, Dr. Feistmantel has shown that the following Damúda forms are common :—

Voltzia, one species identical,		
Albertia ? ditto ?		
Actinopteris, the genus only, the species shewing affinity,		
Sagenopteris,	ditto,	ditto,
Neuropteris,	ditto,	ditto,
Schizoneura,	ditto,	ditto,

or six genera and one or, perhaps, two species. It is quite true, as Dr. Feistmantel has shown, that *Pecopteris* (*Alethopteris*) *Lindleyana* of the Damúdas has nearly as close affinities to certain jurassic forms in Europe as to *P. Australis ;* but, on the other hand, an equisetaceous plant occurring near Nágpúr† was described by Sir C. Bunbury under the name of *Phyllotheca Indica* from a good series of specimens, and considered closely allied to some Australian forms.

On the whole, it appears to be a reasonable conclusion that the evidence which connects the Damúda formation with the Australian carboniferous rocks is about equal to that which tends to show their relations with the Trias of Europe, the only distinction of importance being that the evidence of connection with the Australian beds is so abundant, and the plants which are common to the Trias are (with the exception of *Schizoneura*) so rare, that the latter have hitherto been overlooked.

The evidence afforded by the few animal remains hitherto procured from the Gondwána series is nearly as confusing as that of the plants. From the Kota and Maleri beds now shown‡ to be identical, and to belong to the Upper Gondwána series, we have *Ceratodus*, which in Europe is Triassic or Liassic, but which has been found living in Australia; *Hyperodapedon*, Triassic in Europe, but allied to the living New Zealand genus *Hatteria ;* and certain early mesozoic forms of *Crocodilia*, together with fish (*Lepidotus* and *Echmodus*) with liassic affinities, and *Estheria*, which is insufficient

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* The specimens described by McCoy (Prod. Palæont. Victoria, Decade II, Pls. XII & XIII) are said by their describer to be from the upper coal-bearing strata of Victoria, the position of which is uncertain, but Dr. Feistmantel has detected one species in the beds from beneath the carboniferous marine beds of Newcastle, N. S. W.

† [illegible] Geol. Soc., XVII, p. 335.

‡ [illegible] following paper by Mr. Hughes.

for the determination of age. In the Panchet group of the Lower Gondwána series we have *Dicynodon* showing an affinity for South African strata, other reptiles from which have just been shown by Professor Owen* to be allied to Permian forms found in Russia. The other known Panchet *Vertebrata* are *Labyrinthodonts* and a *Thecodont Saurian*, which, according to Professor Huxley, might be either lower mesozoic or upper palæozoic. Besides these there are the ubiquitous *Estheriæ*. From the Damúda formation (including the Kámthi of Mángali) one *Labyrinthodont* (*Brachyops laticeps*) has been described, the affinities of which appear to be uncertain, an *Archegosaurus*, hitherto only imperfectly examined, and *Estheriæ*. The whole evidence, so far as it goes, both of animals and plants, tends to connect the whole of the Gondwána series with formations ranging from the Upper Palæozoic to the Lower Jurassic.

It must be remembered that the affinities between the plants of the Australian coal-bearing rocks and those of the jurassic beds of Europe are unmistakeable. They have been pointed out by all palæo-botanists, and they extend to some of the plants in the beds interstratified with the carboniferous marine strata.

It would have been useless to recapitulate all these facts, most of which are well known, and none of which are new, did they not lead to a conclusion which appears to me of the highest importance with reference to the ancient distribution of animals and plants.

In the present distribution of the animal kingdom, there is much greater uniformity throughout the globe in the marine than there is in the terrestrial fauna. The former varies chiefly with the depth beneath the sea, and, amongst the shallow water and coast forms, with climate. A collection of Mollusca or Echinodermata (and these are our principal guides in palæontological classification) from the Atlantic, the Pacific, and the Indian Oceans, all taken within the tropics, would afford but few examples of generic distinction. A collection of terrestrial *vertebrata* or *invertebrata* from Tropical America, Northern Australia, Malacca and Africa, would differ from each other, not merely in genera, but, in many instances, in families. The plants from these different tropical lands would also exhibit marked generic distinctions, and whilst many of the American plants would show affinities with the miocene forms found in Europe, numerous representatives would be found, amongst Australian animals and plants, of forms which, in Europe, were typical of mesozoic strata.†

In the evidence now recapitulated, that the plants which existed in Australia, whilst carboniferous forms inhabited the seas, were allied to species and genera of the jurassic flora of Europe, that some of these same forms of carboniferous age in Australia co-existed in India with species found also in the triassic rocks of Europe, and that plants of the lower oolite of England still existed in India, whilst the surrounding seas nourished uppermost oolitic forms, we have convincing proof that the land faunas and floras of palæozoic and mesozoic times differed from each other in various parts of the globe, at least as much as they do in the present day. In short, the conclusions to which we are, I think, brought by a consideration of the evidence are—

1st.—That the faunas and floras of distant lands varied in palæozoic and mesozoic times, as they do at the present day, far more than the fauna of the seas; in short, that there were distinct terrestrial zoological and botanical provinces.

2nd.—That evidence, founded upon fossil plants, of the age of rocks in distant regions, must be received with great caution, and that such evidence is certainly in some cases opposed to that furnished by the marine fauna.

* Geological Society of London: Meeting of May 24th, 1876. Only an abstract of the paper has hitherto reached India.

† It would take up too much space to go into details. *Zamia* and certain *Proteaceæ* amongst plants, *Ceratodus* and the *Marsupialia* amongst animals, are sufficient to establish the general fact.

ON THE RELATIONS OF THE FOSSILIFEROUS STRATA AT MALÉRI AND KÓTÁ, NEAR SIRONCHA, CENTRAL PROVINCES, *by* TH. W. H. HUGHES, A.R.S.M., F.G.S., *Geological Survey of India.*

The fossiliferous strata alluded to in this paper have already been brought to notice directly in the Quarterly Journal of the Geological Society of London,* and incidentally in our own Memoirs,† and various other publications, but hitherto only speculative suggestions as to their mutual relations have resulted, the essential element of stratigraphical evidence having been wanting to complete the data for practical discussion.

This year, however, in the course of a special tour in which I accompanied Mr. King, Deputy Superintendent of the Survey for Madras, we were able to visit Kótá and Maléri, and to trace the extension of the more prominent beds of the one locality into connection with those of the other, thus supplying the needed evidence.

The result we have come to is, that the Kótá and Maléri beds must be classed together, or, at all events, are members of the same series, and that they are younger than the Kámthi, or Kámthi-Damúda series.

The most interesting result of our palæontological researches in the same district was the discovery by Mr. King, in strata below the beds at Kótá, of a *Palissya* which Dr. Feistmantel has identified as a specific representative of one in the Rájmahál series (*Palissya conferta*); while in beds associated with the fossiliferous strata at Maléri, I detected another *Palissya*, referable to a species found in the Jabalpúr group, and also the *Araucarites* of the Kach plant-beds.

The fauna already known from Kótá and Maléri is represented by relics of *Lepidotus*, *Œchmodus*, and *Ceratodus*, with the crocodilian genus *Parasuchus*, *Hyperodapedon*, &c., some of which indicate a Triassic age, whilst none are represented by allied forms in European strata at more recent period than the Liassic.

We thus have associated in the same group plants of our Indian Jabalpúr, Kach, and Rájmahál groups, and animals, which, if judged by European analogy, are certainly not younger than the age of the Lias.

Dr. Feistmantel has recently endeavoured to show that the flora of the Jabalpúr, Kach and Rájmahál groups proves them to be older than the age usually ascribed to them, a view which our discovery tends to strengthen.

NOTES ON THE FOSSIL MAMMALIAN FAUNÆ OF INDIA AND BURMA, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

Introduction.

The present short paper is intended to appear as a kind of preface to full descriptions of several new species of fossil mammalia which have lately been discovered in the tertiary strata of India and Burma, chiefly by Members of the Geological Survey of India. These descriptions will appear in the "Palæontologia Indica," according to the opportunities of publication.

[illegible] Formations.

The formations and districts from which the remains of mammalia have hitherto been discovered in India and Burma are shown in the following lists; these I have arranged according to that which seems to me to be their most probable succession in time; several

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* [illegible] p. 232; IX, p. 321; XVII, p. 349; XX, pp. 117, 230, &c.

† [illegible]; IX, p. 32.

faunæ, such as those of the old alluvium of the Ganges and Jamna, of the gravels of the Nerbudda Valley, and of certain beds of the Deccan, are grouped provisionally together, as they evidently belong to (geologically speaking) the same epoch; at the same time I would observe that these beds are nowhere found in direct apposition, and that, therefore, there may be considerable differences in their age. It is also to be borne in mind that many of these formations containing distinct groups of animals may really be contemporaneous, the difference in their faunæ being caused by physical conditions. After the names of certain genera and species in the succeeding lists, my own name is added; these genera and species are new to the fossil Indian fauna, and full descriptions will subsequently appear in the "Palæontologia Indica."

The following list comprises the known mammaliferous beds of India:—

Indian Mammaliferous Series.

	Modern alluvia* of rivers and plains, containing human remains and bones of living Mammalia.	Recent.
	a.—Old alluvium of Jamna and Ganges.	Post Pliocene or Newer Pliocene.
	b.—Older gravels of Nerbudda and Godávarí.	
	c.—Gravels of the Deccan.	
SIWALIK.	*d.*—Upper Siwalik conglomerates and clays.	
	Siwaliks of Falconer. (Pal. Mem. *passim.*)	
	Mammaliferous sandstones and clays of Jamu. Medlicott: Rec. Geol. Surv., Ind., Vol. IX, pt. 2.	
	Mammaliferous sandstones and clays of Potwar and Kohat districts: (Wynne: Mem. Geol. Surv., Ind., Vol. X, pt. 2.)	Pliocene.
	Marine mammaliferous sandstones of Chittagong and Sylhet	
	Siwaliks (?) of Tibet.	
	Manchhar beds of Sind (and Kach ?)	
	Mammaliferous beds of Pegu and Irawádí River.	
	Mammaliferous beds of Perim Island.	
	Beds at Kushalghar (forty miles south of Attock) ...	Upper Miocene (?)
	Náhan beds of Bakrálá Range	Upper Miocene (?)
SUBATHU	Nummulitic beds of Salt Range and Fatehjang ...	Miocene.

Commencing with the uppermost beds in this list, it will be seen that I have grouped three (*a*, *b*, *c*,) together; the two first are placed together on the authority of Dr. Falconer, who grouped the older alluvia of the Jamna with the older gravels of the Nerbudda valley, on account of the similarity of their faunæ (Pal. Mem., vol. II, p. 580.)—The Upper Siwalik group I have also placed near these beds (see *infra*), on account of the distinctness of its few mammals from those of the underlying beds: at the same time it must be observed that these uppermost beds are conformable to the underlying series, while they are capped by unconformable strata, which may be contemporaneous with part of the river alluvia: it would, perhaps, be best, therefore, to regard these Upper Siwaliks as "transition beds" between the true Siwaliks and the Nerbudda and Jamna series.

The following list of genera and species is given by Falconer (Pal. Mem., vol. II, p. 642) from the older alluvia of the Jamna:—

Euelephas namadicus, Falc.	Bubalus palæindicus, Falc.
Tetraprotodon palæindicus, Falc.	Sus (sp.)
Equus (sp.)	Bos (sp.)
Cervus (sp.)	Antilope (sp.)

In the Indian Museum* we have also specimens of *Mus* and *Semnopithecus* from the same deposits. The whole of the genera in the above list are still living in India with the exception of *Tetraprotodon*, which is now confined to Africa: all the genera (and species at present determined) are also found in the Nerbudda deposits. The mammalian fauna of the Nerbudda and Godávarí deposits presents a somewhat more copious list than the foregoing: many of the species have been figured by Falconer (see "Fauna Antiqua Sivalensis" and "Palæontological Memoirs"), but a few new species are contained in the collection of the Indian Museum. The following is the list from these formations:—

BIMANA.

Man. (stone weapons)

PROBOSCIDIA.

Elephas namadicus, Falc. ... Stegodon insignis, Falc.

PERISSODACTYLA.

Rhinoceros namadicus, Falc. ... Equus namadicus, Falc.

ARTIODACTYLA.

Hexaprotodon namadicus ... Bubalus palæindicus, Falc.
Tetraprotodon namadicus ... Bos namadicus, Falc.
Cervus namadicus, Falc.

CARNIVORA.

Felis (sp. nov. Indian Museum) ... Ursus namadicus, Falc.

RODENTIA.

Mus (sp. nov. Indian Museum).

The topmost Siwalik clay and conglomerates near Bubhor (see Mr. Medlicott's paper, Rec. Geological Survey, India, vol. IX, pt. 2; p. 57) have yielded to Mr. Theobald's careful search two species of Mammals, *viz.*, *Bubalus palæindicus* and *Camelus sivalensis*. As the first of these species is unknown amongst the subjacent Siwalik Fauna, and as the second is an essentially modern form, I have chosen to group these uppermost Siwaliks with the Nerbudda beds rather than with those lying below them. Mr. Medlicott, however, is rather inclined to doubt this view.

Living genera.

It will be observed that in the above lists, the whole of the genera, with the exception of *Hexaprotodon* and *Stegodon* (which are really only sub-genera), are still living on the globe, and among the living genera, with the exception of Hippopotamus, the whole number are still living in India. None of the fossil species have, hitherto, been satisfactorily identified with living forms; one species of deer is, however, very closely allied to the living Indian *Rucervus* (as I shall show in a subsequent paper); and the *Bubalus palæindicus* (as far as craniological characters go) is scarcely separable from the *Bubalus arni* of India. The presence of a true taurine ox (*Bos namadicus*) in these beds marks the distinctness of this fauna from that of modern India, but, at the same time, such a highly specialized form confirms the very recent age of these formations.

Certain species of Ruminants, such as *Bos Falconeri* and *Cervulus stylocerus* described by Mr. Theobald from the Nerbudda valley (Mem. Geol. Surv., India, vol. II, p. 279), are founded on bones of *Bos namadicus* and *Rucervus*.

* [illegible] figured in the Journal of the Asiatic Society, Bengal (vol. II, p. 85), as human from these beds, were shown by Falconer to belong to other mammalia.

Deccan beds.

The last fomation which I have provisionally placed in this newer group consists of certain gravels and clays from the Deccan, containing Mammalian remains, some of which have been described by Mr. Foote (Pal. Ind., Ser. X, Vol. II).

The fauna at present only comprises three genera, two of which are only known by fragments, and cannot be specifically determined. These are—

Rhinoceros deccanensis (Foote).
Bos (sp). Equus (sp).

Mastodon pandionis, Lartet, has also been described by Falconer from superficial beds in the Deccan ("Palæontological Memoirs," Vol. I, p. 124).

These gravels being superficial and undisturbed, point to the comparatively modern age of the beds: the bones, too, are in an extremely friable and rotten condition, which would induce one to think that had they been buried for long geological periods in this pervious soil, they would have completely perished. At the same time, the molars of the species of Rhinoceros are so different from those of any living or fossil Indian species, that I cannot help thinking these beds may be older than those of the Nerbudda valley, or, at any rate, that the Rhinoceros is one of the last survivors of an older fauna.

The very peculiar and prominent "cingulum" on the premolars of this species indicates considerable relationship with the older *Acerotherium* and *Palæotherium*. If Falconer is right in identifying the Deccan *Mastodon* with *M. pandionis*, this is the only instance of a fossil Indian Mammal being identical with a European species.

Pliocene.

The different groups of strata included under this head comprise those beds which have produced the greatest number of fossil Mammalia: I have included under the head of Pliocene-Siwalik nearly the whole of the Mammaliferous beds of the Sub-Himalayan region (with the exception of the topmost beds noted above), because we have hitherto found no distinction in the Mammalian Fauna of the different beds. Few identifiable Mammalian fossils have yet been discovered from the Náhan beds of Mr. Medlicott (Mem. Geol. Surv., India, Vol. III, p. 101), nor from what appear to be their corresponding beds in the Jamú and Potwar country (Rec. Geol. Surv., India, Vol. IX, pt. 2) described by Mr. Medlicott. The main exception to this are certain fossils, to be subsequently noticed, coming from the south of Attock.

Mr. Wynne (Mem. Geol. Surv., India, Vol. X, pt. ii, p. 24) has proposed to identify the grey sandstone and brown-clay series of the Potwar and Kohát districts with the Náhans of Mr. Medlicott: this, I believe, partly arose from a mistaken conception of the geological age of certain fossils collected by Mr. Theobald in the Kángra and Jamú districts: these fossils were all collected from Siwalik and not from Náhun beds, and as they agree specifically with those from Mr. Wynne's grey and brown beds, I have no hesitation in placing these, on palæontological grounds only, as of Siwalik age: Mr. Medlicott agrees with this view (Rec. Geol. Surv., India, Vol. IX, pt. 2, p. 56).

The whole of the Mammalian fossils (with the exception of those from near Attock), described by the late Dr. Falconer, were, I have not the least doubt, obtained from the typical Siwalik horizon of Mr. Medlicott; and there is, therefore, no ground for the suggestion which has been made, that Dr. Falconer erred in not making a distinction between Siwalik and Náhun Mammalian fossils. The divisions in the Siwalik strata, founded on lithological characters only, I have not noticed, as they do not, as far as we know at present, contain distinctive groups of Mammalia.

The following is the list of Fossil Mammalia at present known to me from the Sub-Himalayan Siwaliks:—

PROBOSCIDIA.

Stegodon insignis, Falc.	Euelephas hysudricus, Falc.
Stegodon bombifrons, Falc.	Mastodon latidens, Falc.
Stegodon ganesa, Falc.	Mastodon sivalensis, Falc.
Loxodon planifrons, Falc.	

PERISSODACTYLA.

Rhinoceros platyrhinus, Falc.	Equus sivalensis, Falc.
Rhinoceros sivalensis, Falc.	Equus palæonus, Falc.
Rhinoceros palæindicus, Falc.	Hippotherium antilopinum, Falc.
Acerotherium perimense, Falc.	Listriodon sp. mihi.

ARTIODACTYLA,—Suina.

Hexaprotodon sivalensis, Falc.	Sus giganteus, Falc.
Merycopotamus dissimilis, Falc.	Sus hysudricus, Falc.
Tetraconodon magnum, Falc. et mihi.	Hippohyus sivalensis, Falc.

ARTIODACTYLA—Pecora.

Chalicotherium sivalense, Falc.	Bison sivalensis, Falc.
Camelus sivalensis, Falc.	Hemibos triquetriceros, Falc.
Sivatherium giganteum, Falc.	Amphibos acuticornis, Falc.
Camelopardalis sivalensis, Falc.	Peribos occipitalis, Falc. et mihi.
Dorcatherium, 2, sp. mihi.	Bos, sp. var. Indian Museum.
Capra, sp. Brit. Mus.	Cervus, sp. var. Indian Museum.

CARNIVORA.

Felis cristata, Falc.	Hyænarctos sivalensis, Falc.
Felis palæotigris, Falc.	Amphicyon, sp. mihi, Indian Museum.
Drepanodon sivalense, Falc.	Ursitaxus sivalensis, Falc.
Hyæna sivalensis, Falc.	Lutra palæindica, Falc.
Canis, sp. Brit. and Indian Museum.	Enhydriodon ferox, Falc.

RODENTIA.

Hystrix, sp. Falc.	Mus sp. Falc.	Typhlodon sp. non-desc, Falc.

QUADRUMANA.

Semnopithecus Sub-Himalayanus, Meyer: and Macacus.

Several species mentioned in the manuscript notes of the late Dr. Falconer, but never described, and of which the original specimens are now unknown, have been omitted from the above list, as it is quite impossible to identify them. *Camelopardalis affinis* of Falconer has also been omitted, because the species appears to me to have been founded on a mistake. (See Appendix.)

Referring to the table of formations given above, we find the next on the list to be certain beds at Chittagong; these beds I have never seen, nor am I aware that they have been described: they are inserted here on the evidence of a small collection of fossils from the above locality in the Indian Museum. These fossils are imbedded in a coarse green sand matrix, and comprise two or three genera of marine shells, with teeth of *Lamna*, and two Mammalian molars: one of the latter I have identified with *Sus hysudricus* of the Siwaliks; the other is the molar of a species of *Cervus*, apparently new; of course till more specimens are obtained from this district, it would be rash to speculate as to the age of the beds, though they may very probably be Siwalik.

The next formation on the list is the Mammaliferous series of *Pegu* and the *Irawadi* river: fossils from these beds have been described and figured by Dr. Falconer ("Fauna Ant. Sival." and "Pal. Mem."), and by Mr. Clift (Trans. Geol. Soc., London, 2nd series, vol. 4); several new species of Mammals from this district are contained in the collection of the Indian Museum, obtained by Mr. W. T. Blanford and Mr. W. Theobald. The following list contains only those species of which the locality is certain:—

PROBOSCIDIA.

Stegodon Cliftii, Falc.	Mastodon latidens, Falc.
Mastodon sivalensis, Falc.	

PERISSODACTYLA.

Rhinoceros n. sp. mihi, Ind. Mus.	Equus sp. Ind. Mus.
Acerotherium perimense, Falc.	Tapirus, Clift.

ARTIODACTYLA.

Hexaprotodon iravadicum, Falc.	Bos. sp. Ind. Mus.
Merycopotamus dissimilis, Falc.	Cervus sp. Ind. Mus.
Vishnutherium iravadicum n. gen. mihi.	

CARNIVORA.

Ursus sp. Indian Museum.

The fauna of the (probably) Siwalik strata of the Niti Pass and Tibet is only known from a few fragments of bone described by Dr. Falconer ("Pal. Mem.," Vol. I, p. 175), and from certain fossils collected by General Strachey (Quar. Journ. Geol. Soc., London, Vol. VII, p. 292); these comprise remains of a species of Rhinoceros, and of a ruminant allied to *Ovis* or *Capra.*

The mammaliferous strata of Sind, with which I should be disposed to group those of Kach, have been recently described by Mr. W. T. Blanford (Rec. Geol. Surv., India, Vol. IX, pt. 1) under the name of Manchhar beds, which he correlates with the Sub-Himalayan Siwaliks; the only genera which I can at present identify among the numerous fragments of bones collected by Mr. Fedden from these deposits are the following:—

PROBOSCIDIA.

Mastodon latidens, Falc.	Stegodon sp.
Dinotherium sp. mihi.	

PERISSODACTYLA.

Rhinoceros, 2 sp. mihi.	Listriodon sp.

ARTIODACTYLA.

Merycopotamus sp. mihi.	Ruminant sp. (astragalus.)
Chalicotherium. sp.	

The last beds that I have introduced into the pliocene group are the mammaliferous gravels of Perim Island, in the Gulf of Cambay; most of the species were noticed by Falconer; the list comprises—

PROBOSCIDIA.

Mastodon latidens Falc.	Dinotherium indicum, Falc.
Mastodon perimensis Falc.	

PERISSODACTYLA

Acerotherium perimense, Falc.	Rhinoceros sp. non-des.

ARTIODACTYLA.

Bramatherium perimense, Falc.
Camelopardalis sp. Falc.
Capra, sp. mihi. Ind. Mus.
Antilope sp. mihi Ind. Mus.
Sus hysudricus Falc.

The Mammalian fossils which I have provisionally placed under the head of Miocene comprise three groups; the first of these is from Kushalghar, forty miles to the south of Attock. In the early part of the present year I made a journey to Attock for the purpose of re-discovering the beds from which these fossils had been obtained; unfortunately I had not been correctly informed as to the precise locality at which the fossils had been found, and I was consequently unsuccessful in the main object of my journey. The exact horizon of these beds must therefore be still an unsettled question: from the marked difference between their small fauna and that of the typical Siwalik area, I am inclined to think that they may belong to a somewhat earlier period, such as the Náhan of Mr. Medlicott; red strata corresponding to the latter occur in the neighbourhood from which the fossils were obtained. The original specimens from this locality are now in the Indian Museum; those to which Falconer's name is added in the following list were shortly noticed by him in a manuscript note ("Pal. Mem., Vol. I, p. 415); the following list contains all the species known to me from this locality;—

PROBOSCIDIA.

Mastodon sp. Ind. Mus.
Dinotherium pentapotamicum, Falc.

PERISSODACTYLA.

Listriodon pentapotamiæ, Falc. (gen. mihi.)
Rhinoceros sp. n. Ind. Mus.
Antoletherium, Falc.

ARTIODACTYLA.

Merycopotamus sp. mihi.*
Dorcatherium sp. mihi.
Sus pusillus, Falc.

CARNIVORA.

Amphicyon sp. n. Falc.

With regard to other formations below the typical Siwaliks, the fossils are so few and so fragmentary, that very few of them can be specifically determined. Mr. Wynne has collected a fragmentary tooth of a species of *Mastodon* from the Náhan beds of the Baktrálá range near Jhilum. From the Sabáthú nummulitic beds of Fatehjang and its neighbourhood Mr. Wynne has obtained a considerable series of bones, but mostly in a very unsatisfactory condition.

From the beds immediately overlying the Mammaliferous clays of Fatehjang, I have recognised the perfect astragalus of an Artiodactyle animal; the form of this bone shows that the navicular and cuboid were united; the animal was therefore probably a Ruminant. From the Sabáthú nummulitics we have a femur of a Perissodactyle animal allied to *Rhinoceros*. These are the oldest Mammalian remains yet discovered in India.

Having now shortly noticed the faunæ of the various Mammaliferous beds of India, it remains firstly to consider their relationship one to another, and subsequently the relationship of the whole group to the living and fossil Mammalian faunæ of other regions of the globe.

* See Appendix.

On looking through the foregoing lists, it will be observed that there is but one species of Mammal common to the faunæ of the Nerbudda beds and the lower Sub-Himalayan Siwaliks, *viz.*, *Stegodon insignis;* the remains of this species are far less common in proportion to those of other animals in the Nerbudda beds than in the Siwaliks: this fact indicates that the species was rapidly dying out in the latter period, beyond which the genus is unknown. *Bubalus palæindicus* has been quite lately discovered (in company with *Camelus sivalensis*) in the topmost beds of the Siwaliks, which have not hitherto yielded other Mammalian remains: as this species is not found in the lower Siwaliks, I have placed these uppermost beds in near relation to the Nerbudda beds. Since, as noticed above, the genera *Hippopotamus* and *Stegodon* are the only forms at present not generically represented among the living Indian fauna, there can be no doubt as to the very modern age of these deposits.

The only two species of Mammalia at present satisfactorily determined to be common to the Sub-Himalayan, Irawadi, and Perim Island beds are *Acerotherium perimense* (this species was added last year to the Siwalik Fauna by Mr. W. Theobald's discovery of two well-preserved upper molars in these strata) and *Mastodon latidens.*

Both the species of *Mastodon,* which occur in the Siwaliks, are also found in the Irawadi beds; but the *Rhinoceros* of the latter deposits is very markedly distinct from any of the Siwalik species. (The molars of the Irawadi *Rhinoceros* in the Indian Museum I shall describe on a future occasion.) The species of *Hexaprotodon* are also different in the two deposits: the same species of *Merycopotamus,* however, occurs in both. *Stegodon cliftii* appears to be peculiar to the Irawadi beds; it is the species most nearly allied to the *Mastodons,* and is therefore probably the oldest of the genus; teeth of *Mastodon* are very common in these beds, while true elephants appear to be absent; but I cannot lay great stress upon this point at present; if the absence of *Euelephas* be confirmed by a more thorough examination of these strata, I should be well-nigh sure that these beds are older than the Siwaliks. A new genus of Ruminant, for which I propose the name of *Vishnutherium,* closely related to, but smaller than, *Sivatherium* and *Bramatherium,* has been determined by me from a portion of a lower jaw with teeth obtained from these beds by Mr. W. T. Blanford. Remains of specialised Ruminants like *Cervus, Bos,* and *Antilope,* as also of *Equus,* are far more rare in the Irawadi beds than in the Siwaliks—facts probably pointing to the somewhat older age of the former.

From the Mammaliferous beds of Perim Island, *Acerotherium perimense* and *Mastodon latidens* are the only two Mammals which I have been able satisfactorily to identify with the Siwalik fauna; the one molar of *Sus* from Perim in the Indian Museum seems, however, to be the same as the Siwalik *Sus hysudricus.* All the other species at present determined are peculiar to this district: out of seven genera, four are quite extinct, and two of these, *viz.*, *Dinotherium* and *Bramatherium,* are not found in the typical Sub-Himalayan Siwaliks. The presence of the former of these genera indicates a relationship between this fauna and that of Sind, and the Attock beds.

The extinct Mammalian fauna of the Siwaliks of Sind, as far as it is at present known, seems to indicate a group distinguished from that of the typical Sub-Himalayan deposits. Among the small but interesting collection of fossils brought from this district by Mr. Fedden, I notice the absence of *Equus* and Bovoid Ruminants, and the presence of *Dinotherium, Dorcatherium,* and *Merycopotamus* (all extinct). *Listriodon* has been found in these beds, and single teeth have been obtained from Attock and the Potwar (Theobald), but not from the true Siwaliks of Falconer: it would therefore seem probable that this genus in tertiary times was confined to the western side of Upper India, not ranging into the Ravi and Satlej districts. Two species of *Rhinoceros* have been brought by Mr. Fedden from

these beds: one of them is different from either of the Siwalik species, and allied to *R. deccanensis* of Mr. Foote, while the other approaches to *R. palæindicus*. The species of *Listriodon* appears to me to be the same as *Listriodon pentapotamiæ* from Attock. I think it probable from this fauna, either that it was separated from the typical Siwalik fauna by physical barriers, or that it might have been slightly older. Mr. Fedden tells me that the Mammals from these deposits are found nearly at the base of the fresh-water series; in the Potwar district, on the other hand, they occur nearly at the top: this suggests that the Sind fauna is somewhat the older.*

The fauna of the Kushalghar beds near Attock comprises a small group of Mammalia, in which the species and in many cases the genera are quite distinct from those of the typical Siwalik area; all the specimens from this locality are molar teeth in an excellent state of preservation, so that there can be no doubt as to the correctness of their specific identification; the fossils are embedded in a red clay matrix, which lends confirmation to my suggestion that they may belong to the Náhun zone of Mr. Medlicott. Among a total number of nine genera from these beds no less than five are extinct; one of these genera, *Dinotherium* (as noted above) is unknown in the typical Siwaliks; while another, *Antoletherium*, is peculiar to these beds: a third, *Amphicyon*, is only known in the typical Siwaliks, from a single carnassial tooth of the lower jaw brought by Mr. Medlicott from the red-clay and sandstone beds of Núrpúr (these beds are placed quite at the base of the Mammaliferous Siwaliks); the Attock specimen, which is an upper true molar, must have belonged to a much smaller animal than the Siwalik specimen; and the two species were doubtless distinct. The *Merycopotamus* of the Kushalghar beds seems to be the same as the Siwalik and Burmese species †; a lower molar of *Rhinoceros*, from the same locality, is quite distinct from those of either of the Siwalik species of the genus. A species of *Dorcatherium* from these beds may or may not be distinct from Falconer's Siwalik species, the original and description of which seems to have been lost, the name only appearing in a manuscript note. A very small and distinct species of *Sus* (the animal could scarcely have been larger than Hodgson's *Porcula salvania*) is also peculiar to these beds. *Listriodon* has only just been found in the Siwalik strata by Mr. Theobald; it existed in the lower Miocene of Europe: I think the Siwalik species is the same as Falconer's *Listriodon pentapotamiæ*.

Apart, therefore, from the position of these Kushalghar beds in the geological series, their Mammalian fauna is found to be very markedly distinct from that of the Siwaliks, From the presence of such, simple forms as *Antoletherium Dinotherium* and *Listriodon* together with *Amphicyon* and *Dorcatherium*—all European Miocene forms—and from the absence, hitherto, of all such specialized types as *Bos*, *Elephas*, *Equus*, &c., we are led to place this fauna in closer connection with the ancestors of the true Siwalik fauna. Whether the age of the fossils is really pre-Siwalik, or whether the animals from which they were derived lived in part contemporaneously with the Siwalik fauna, but shut off from it by physical barriers, must remain an open question until the exact position of the beds is determined; at all events there seems to be a distinctness in the fauna of all the Mammaliferous beds of the western side of India from those of the typical Siwaliks of Falconer. *Dinotherium* and *Listriodon* are only found at Attock, in Sind, and at Perim. The above comparisons tend to show that the Burmese Fauna, though different, still

* In my note on *Stegodon ganesa* (Rec. Geol. Surv. India, Vol. IX, pt. 2, p. 45) I made the error of calling these beds "supra-nummulitic" instead of Siwalik. Mr. Blanford's paper on Sind was not published when I wrote

† Appendix.

has considerable relations to the Siwalik, indicating some land connection between the two areas, perhaps something like that which exists at the present day; on the other hand, the Faunæ of Perim Island and the Kushalghar beds are markedly distinct. Nothing definite can at present be predicted regarding the other beds.

Having now shortly glanced at the relations of the fossil fauna among themselves, we may consider their relations firstly to the present fauna of the globe, and secondly to the fossil fauna of other regions. The lists given above (excluding the Post-Pliocene period) contain upwards of forty-six well established genera of Mammalia; of these, the following twenty-five, or rather more than one-half of the total number, are now extinct, *viz.*:—

PROBOSCIDIA, *Mastodon, Stegodon, Dinotherium.*

PERISSODACTYLA, *Antoletherium, Acerotherium, Hippotherium, Listriodon.*

ARTIODACTYLA, *Hexaprotodon, Tetraconodon, Merycopotamus, Hippohyus, Bramatherium, Vishnutherium, Sivatherium, Hemibos, Amphibos, Peribos, Dorcatherium, Chalicotherium.*

RODENTIA, *Typhlodon.*

CARNIVORA, *Drepanodon, Amphicyon, Hyænarctos, Ursitaxus, Enhydriodon.*

Of the remaining genera there are now found living in India or the adjacent countries the following seventeen, *viz.*:—

PROBOSCIDIA, *Euelephas.*

PERISSODACTYLA, *Rhinoceros, Equus.*

ARTIODACTYLA, *Cervus, Antilope, Capra, Bison (Poephagus), Bos (Bibos), Sus.*

RODENTIA, *Hystrix.*

CARNIVORA, *Felis, Hyæna, Lutra, Canis, Ursus.*

QUADRUMANA, *Semnopithecus, Macacus.*

The above list shows that rather more than one-third of the genera of the middle tertiary Mammalia of India are still living in Asia; if now we turn to the living Mammalian fauna of Africa, we find the following twelve genera common to it and to the Indian Tertiary Mammalian Fauna, *viz.*:—

PROBOSCIDIA, *Loxodon.*

PERISSODACTYLA, *Rhinoceros, Equus.*

ARTIODACTYLA, *Hippopotamus (representing Hexaprotodon), Bubalus, Camelopardalis, Capra, Antilope.*

CARNIVORA, *Hyæna, Lutra, Felis, Canis.*

As being closely connected with our present subject, we may notice here the great number of living Mammalian genera common to the continents of India and Africa (south of the Sahara). The following list of forms (exclusive of Cheiroptera) common to the two continents was kindly given to me by Mr. W. T. Blanford; it comprises twenty-three genera, *viz.*:—

PROBOSCIDIA, *Elephas* (*Loxodon* in Africa *and Euelephas* in India.

PERISSODACTYLA, *Antilope (subgenera), Gazella, Capra, Bubalus.*

SIRENIA, *Halicore.*

RODENTIA, *Sciurus, Hystrix, Mus, Gerbillus, Lepus.*

INSECTIVORA, *Erinaceus, Sorex (Crocidura).*

CARNIVORA, *Felis (sp. leo.* and *leopardus), Canis, (sp. aureus), Mustela* (Himalayas), *Hyæna, Viverra Paradoxurus, Lutra, Aonyx, Herpestes, Mellivora.*

Again, we find the twenty-six following genera common to the Indian Tertiaries and to the Tertiaries of Europe, *viz.* :—

PROBOSCIDIA, *Mastodon, Loxodon, Euelephas, Dinotherium.*
PERISSODACTYLA, *Rhinoceros, Acerotherium, Equus, Hippotherium, Listriodon.*
ARTIODACTYLA, *Hippopotamus, Sus, Chalicotherium, Dorcatherium, Cervus, Bos, Bison, Capra, Camelopardalis.**
CARNIVORA, *Amphicyon, Ursus, Felis, Drepanodon, Hyæna, Lutra, Hyænarctos, Canis.*

From the above list we find that more than half the number of genera of Mammalia which occur in the Indian Tertiaries are also found in the Tertiary fauna of Europe. In contrast to this if we turn to the living fauna of Europe, we find the following eight genera common to it and the Indian Tertiary fauna, *viz.* :—

ARTIODACTYLA, *Sus, Bos, Bison, Capra, Cervus.*
CARNIVORA, *Ursus, Felis, Lutra.*

Finally we find the following fourteen genera peculiar to the Indian Tertiaries :—

PROBOSCIDIA, *Stegodon.*
PERISSODACTYLA, *Antoletherium.*
ARTIODACTYLA, *Hexaprotodon, Tetraconodon, Merycopotamus, Hippohyus, Peribos, Hemibos, Amphibos, Sivatherium, Bramatherium, Vishnutherium.*
CARNIVORA, *Ursitaxus, Enhydriodon.*

From the foregoing we arrive at the following results: firstly, that all the species of Mammalia found in the Indian Tertiaries below the Nerbudda beds are extinct; and that the following are the relations of the genera :—

Extinct	25
Peculiar to Indian Tertiaries	14
Common to Indian and European Tertiaries	26
Common to fossil and living Indian fauna	17
Common to Indian Tertiaries and modern Africa ...	12
Common to Indian Tertiaries and modern Europe ..	8

The greatest number of genera common to any two periods occur in the Tertiaries of Europe and India; next to them the greatest common number is found in the living and fossil Indian fauna; thirdly, a small number of genera is common to the extinct fauna of India, and the living fauna of Africa; a few genera are common to the extinct Indian fauna and the modern European fauna; while a larger number of genera are common to the living faunæ of India and Africa.

The above results appear clearly to point to some former connection by land between the continents of India, Africa and Europe. The former land connection between India and Africa has been strongly insisted upon by several modern naturalists; this ancient land connection has been named "Indo-Oceania" by Mr. H. F. Blanford in a recent paper, (Quart. Jour. Geol. Soc. Lond., November 1875) by which name it will be cited here. The writers who have argued for the existence of this ancient continent have been led to form their opinions by the study of their own particular branches of science; another line of evidence derived from the fossil Mammalia cannot but add strength to the hypothesis.

* [illegible] Miocene of Attica; and perhaps in France; see Gervais, Palæontologie et Zoologie Française, p. 142.

Assuming the truth of this hypothesis, we must, in considering the relations of the extinct to the modern fauna of India, divest ourselves of the idea of peninsular India being connected by means of the Himalaya with Central Asia; rather we must look upon it as having been disconnected from the latter region by a deep Eo-Miocene sea, which deposited the extensive nummulitic formations of the Himalaya and Persia; and as having been connected by the old "Indo-Oceania" with Africa, and so with Europe. Subsequently to the (at all events partial) upheaval of the nummulitic series and its overlying sandstones and red clays, the great fresh-water Mammaliferous series was deposited: and it becomes an interesting question to consider whether these were deposited previously or subsequently to the submergence of "Indo-Oceania."

Before there can be any chance of answering this question, the geological age of the Siwaliks must be certainly fixed; whether in fact they should be placed in the Miocene or Pliocene period. The number of extinct genera of Mammalia in these beds is so large, that on first thoughts one would be at once inclined to say that they cannot be of later age than Miocene: this view was taken by Dr. Falconer, and has been subsequently acquiesced in by most other writers. In considering this question we must, however, bear in mind, that it does not at all follow that the same rule holds good in India as in Europe; changes of climatal and physical conditions, and consequently of the forms of life, may have been infinitely more rapid in the one region than in the other.

Besides the Mammalian remains, a considerable number of species of Mollusca have been collected from the Siwaliks; these were sent by Dr. Falconer to the late Prof. E. Forbes for determination; a considerable number were identified with living forms, and Mr. Theobald now tells me that he believes (owing to the more complete collections of living species now extant) nearly all are identical with living species. At the end of his note on the subject (Pal. Mem., Vol. 1, p. 390) Prof. Forbes says that the Molluscan evidence tends to place the age of the Siwalik Fauna as not newer than older Pliocene; if, however, Mr. Theobald's suggestion turn out to be correct, the age would, from the Molluscan evidence, be later than this. In the first volume of the Palæontological Memoirs (p. 26) it is stated that in the opinion of a then eminent authority (Mr. Benson), nearly if not quite all the Siwalik shells were identical with living species. Our collection of these shells in the Indian Museum is not at present very extensive; if additional specimens be obtained, it would be very important to have the whole series carefully compared with their living congeners.

There is, however, the still more important fact, that the Gharial of the Siwaliks, and one species of Crocodile, are absolutely indistinguishable from their living Indian representatives, whilst there is, I believe, no instance of reptiles having survived from the Miocene to the present period. Both of the above facts to my mind point very strongly to the Pliocene age of the Siwaliks: *Emys tectum* is also another Siwalik Reptile which has survived down to the present time.

Another very important piece of evidence tending to the same view is afforded by a statement of Mr. W. T. Blanford's (Rec. Geol. Surv. India, Vol. IX, pt. 1, p. 18) in his Geology of Sind; it is there shown that the Manchhar beds, which he correlates with the Siwaliks (and from the few fossils brought from them, I should say that they cannot possibly be newer) rest unconformably on beds "which are at the oldest Upper Miocene." If this identification is certain, it at once disposes of the Miocene theory of the age of the Siwaliks.

The assemblage of Mammalian genera in the Siwaliks, and other Indian Tertiaries, is so incongruous, according to our ideas derived from the European fauna (as was long since pointed out by Dr. Falconer), that it seems to be impossible from this alone to decide their age. Forms such as *Chalicotherium*, *Acerotherium* and *Dorcatherium* are very characteristic of the Miocene of Continental Europe; but then we find mixed with them such

markedly modern forms as *Equus*, *Hippopotamus* and *Bos*, just as characteristic of the Pliocene in Europe; and it is from the presence of these and kindred genera that I am inclined to give my adherence to the view of the modern age of these strata; rather than, led away by the presence of older forms, which might well have lived down to a later period in this country than in Europe, to place the Siwaliks in the Miocene period. Mr. W. T. Blanford, in the paper above quoted (page 18, note), attaches much weight to the presence of specialised Ruminants in the Siwaliks, as indicating their Pliocene age: and the absence of genera like *Palæotherium* and *Anoplotherium*, as far as negative evidence goes, also tends to prove the modern age of the Siwaliks; with regard to Mr. Blanford's remark, however, it is mentioned in the report on the Miocene Mammals of Attica (Compt. Rend Vol. LI, p. 1296) that "L'abondance des Ruminants est remarquable à Pikermi:" and yet the strata are placed as Miocene.

Assuming, however, the Pliocene age of the Siwaliks, and the former connection of India with Africa, we still have to account for the number of generic forms common to Tertiary India and Tertiary Europe: this, however, presents no difficulty, because it is, I believe, a well-established fact that Southern Europe and Northern Africa were connected by land in middle tertiary times; so that a land communication (not necessarily continuous at any one period) must have once existed between India and Europe, across the Indian Ocean, allowing of the free migration of the Mammalia of the three great continents.

According to this view of the case, we may readily conceive how a European Miocene genus like *Helladotherium* or *Camelopardalis* (both found fossil on the extreme southern borders of Europe) may have lived in these regions, in Northern Africa and in the intermediate submerged land, and so may have given origin to the *Camelopardalis* of the latter continent, and also to the *Sivatherium*, *Bramatherium* and Giraffe of the Indian Tertiaries, which lived in the succeeding Pliocene period. The same may be said of *Elephas* and *Hippopotamus*, some forms of both of these genera being found either living or fossil in all the three continents; both genera might have taken their origin in the Miocene "Indo-Oceania," or adjacent lands, and thence spread out on all sides; to live in one continent up to Pliocene and Post-Pliocene times only, and in the other two to exist up to the present day.

The presence of such genera as *Equus* and *Bos* in the Pliocene of Europe, and in the Siwaliks of India—genera which are still living in both continents—appears to lead to the conclusion that the connecting land between India and Europe must have existed down to a comparatively modern period: and that perhaps some portion of the Siwalik strata were deposited during the period of this union.

The very large number of Mammalian genera common to the Indian and European Tertiaries, and the comparatively small number common to the former and to the living Fauna of Europe, seem to point to an earlier separation between India and Europe than between India and Africa; the Faunæ of the two latter countries still have so many forms in common, that it appears only a relatively short period of time can have elapsed since their separation; a period not long enough to have modified the genera, and in several cases not even the species. Between India and Europe, on the other hand, the relationship between the living Mammalian genera is much less close; and we have to go back to the Miocene period of the latter country, and to the Pliocene period of the former, to find conclusive evidence of a former land communication between the two. Still, as before said, certain living genera are now common to both countries, and we must bear in mind that, assuming the former union of the three great continents of the old world, India and Europe would be situated at the two ends of the chain, and that, therefore, their faunæ would naturally

differ most: moreover, the continents of modern India and Europe differ now (irrespective of what may have occurred in Tertiary times) very greatly in climate, and to this cause alone we may attribute in great part their present divergence in faunæ.

If a more complete series of Mammalian remains should hereafter be discovered in the Tertiary strata of Africa, we may confidently expect to find among them more conclusive evidences of the former mingling of the faunæ of the three great continents of the old world. Among the few Mammalian remains which have been obtained from the upper Tertiaries of Algiers, there is a species of *Bubalus* (*B. antiquus*: see Gervais' "Zoologie et Palæontologie," 1st series, pl. XIX), which approaches much nearer in the form of its cranium to *Bubalus arni* of India, than to any living African species of the genus; certain characters, however, relate it to *B. brachyceros* of the latter continent. Intermediate forms like the above afford the most conclusive evidence of the former connection of the two continents.

The presence of two or three genera of Mammalia in the Siwaliks seems to indicate that at some period of time the fauna of the Indian region must have had communication with the progenitors of the American Fauna; for instance, the genera *Mastodon* and *Equus* are common to the Tertiaries of Europe, Asia and America: *Sivatherium* is not only related by the form of its molar teeth to *Camelopardalis* and *Megaceros*, but in the structure of its horn-cores it approaches the American *Antilocapra*, and no other living Mammal. *Camelus*, again, which is found fossil in the Indian Tertiaries, and in no other formations in the world, must have had some relationship with the ancestors of the Lamas and Vicuunas of the Cordilleras: a fact which I have just discovered confirms this point: the Siwalik camel presents a peculiarity in the lower molars which is not found in the living species, but exists only in the American *Auchenia*.* If camels exist wild in Turkestan, the presence of the genus among the Siwalik fauna is one of the few instances in which that fauna is related to the fauna of Central Asia.

No remains of *Edentata* (now sparingly represented in India) have hitherto been described from the Siwaliks. *Insectivora* are likewise unknown; and no specimens of *Rodentia* have been obtained since Falconer's original specimens. As is so generally the case among older faunæ, many of the Tertiary animals of India vastly exceeded in size their modern representatives; as instances we may note, *Stegodon ganesa*, *Sivatherium*, *Bramatherium*, *Rhinoceros platyrhinus*, *Hyænarctos sivalensis*, and above all *Colossochelys gigantea*.

With regard to the presence of man among the fossil fauna of India, it will be noticed that the discovery of a stone weapon in the gravels of the Nerbudda by Mr. Hacket, and of another by Mr. Wynne, in the Godávari Valley, have confirmed the suggestion of Dr. Falconer (Pal. Mem., Vol. II, page 577) that man would one day be found in these deposits. No traces, however, of man have yet been discovered in the Siwaliks, though Falconer thought they might occur even here; and on the theory of these beds being Pliocene, occurrence of human remains is still more probable; even yet I think all hope of finding them is not exhausted, especially when we remember how very rare are the remains of any Mammals of the anthropoid type; the one tusk of an Ape allied to the Orang, found by Falconer (Pal. Mem., Vol. II, page 578) is still the only specimen of the species hitherto discovered among the many thousands of specimens brought from these deposits. It must also be borne in mind that the whole of the Siwalik fossils are derived from strata and not from caverns, and that, therefore, the chance of finding human remains among them is so much the less.

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* This peculiarity will subsequently be fully described.

Lastly, I would conclude with a few words as to the past and present physical features of the Siwalik region, and as to the causes which have led to the complete extinction of the old Fauna. My remarks will chiefly have reference to that portion of the Siwalik area lying between the rivers Satlej and Indus, as being that with which alone I am personally familiar.

The present Siwalik hills consist of a series of comparatively low ranges, with a general north-west strike, forming the outermost bands of the Himalaya (see Mr. Medlicott: Mem. Geol. Sur., India, Vol. III, and Mr. Drew: "Jamú and Kashmír Territories"), here and there pierced through and broken up by masses of the underlying formations: even their very topmost beds are contorted and crushed in every conceivable manner, indicating the lateness of the period down to which the upheaval of the Himalaya has extended.

These hills are either completely bare, or are covered with forests of *Pinus longifolia* and *Picea Webbiana*, or with low scrub jungle: the "dúns" between the ridges are generally cultivated and fairly fertile. The rivers are generally confined to narrow channels in deep-cut gorges, and never that I am aware of spread out into lakes: isolated lakes of any size are also very rare. On the uncultivated lands natural herbage (fit for food) is extremely scarce; and in its present condition the country seems to me entirely unfitted for the support of a fauna such as that of which we find the remains embedded in its strata.

Mr. Medlicott, however, has reminded me that the old Moghul Emperors used to hunt the elephant in the Jamú hills; and it therefore seems likely that cultivation must have had a share in rendering this part of the country unfit for the habitation of large game. Further to the east the Siwalik area still abounds in jungle, in which the elephant is found abundantly.

Several of the Mammalia found in the Siwaliks of Jamú belong, however, to genera which live in the open sparingly-watered plains of Africa; such are *Equus* and *Camelopardalis*. The *Hippopotamus*, however, on the other hand, is only found at the present day inhabiting large and deep rivers, with pools and lagoons, and on the banks of which grow abundance of rank and succulent vegetation; and, to my mind, could not have possibly lived in any of the rapidly-flowing rivers of Jamú.

If, on the other hand, we glance back at what might have been, and very probably was the character of the country during the deposition of the Siwalik strata, we may readily imagine a physical condition much more suited to animals like the hippopotamus.

Since, in the Jamú district, at all events, the Siwalik strata are carried up and contorted by the conformable underlying rocks, it is evident that these older rocks have only been raised at a comparatively recent period to the elevation at which we now find them, and that consequently in Siwalik times the whole of the outer belt of the Himalaya must have been much lower than at present. This lower elevation would imply a smaller degree of fall in the rivers (which Mr. Medlicott supposes to have flowed in the same courses in Siwalik times as at present) and these consequently, instead of denuding, would have been depositing in the Siwalik districts, and might have wandered in sinuous courses over extensive marshy plains, spreading out here and there into lakes: under such conditions we may readily imagine the country to have abounded with dense jungles of succulent plants suited for the support of large herbivores like the hippopotamus, rhinoceros, elephant, &c.; the condition of the country was probably more like that of Assam at the present day, where the rhino- [illegible] and buffaloe still exist. Evidence of the former existence of extensive [illegible] these regions is afforded by the vast number of tree-stems found in the Náhan sandstone of Jogi-Tilá near Jhilam, and more sparingly in other places.

During the whole of this "depositing-period" the innermost band of the upper Tertiaries (Nâhans) was probably being gradually upheaved, while its detritus was again deposited in the outer band: in course of time the elevation of the inner regions would become so great as to cause the rivers to begin to cut through the outer Siwaliks, and so gradually to drain the country; the Siwalik strata becoming contorted and crushed as they were slowly upheaved. This gradual draining of the country and consequent disappearance of a great part of the vegetation would, I imagine, have been of itself a power quite sufficient to have caused the total extinction of migration of the old Siwalik Fauna from these regions without invoking the aid of man or any other living agent.

Why some genera like *Camelopardalis* and *Hippopotamus*, apparently as well fitted as *Elephas* or *Rhinoceros* to have survived in other parts of India, should have entirely disappeared from the country, while others like *Sivatherium* should have become totally extinct, it is useless to conjecture in our present state of knowledge.

It may be observed that the whole of the Siwalik Mammalia belonged to genera fitted for life in the plains or in low jungle-clad hills, not barren and lofty mountains: we mark the presence of genera like *Elephas, Camelus, Camelopardalis, Equus, Hippopotamus,* and *Rhinoceros,* and note the rareness of *Capra, Ibex, Ovis, Nemorhædus,* and similar mountain genera. Certain beds in Tibet (General Strachey, sup. cit.), however, presumably of Siwalik age, have yielded either an *Ovis* or *Capra:* the further exploration of these strata would probably show a more intimate connection between their fauna and that of Central Asia than is found to exist between the latter and the typical Siwalik Fauna.

APPENDIX A.

Descriptions of some new or little known Mammalia from the Indian Tertiaries.

TETRACONODON MAGNUM, Falconer.

This genus was originally founded by Falconer upon two upper molar teeth from Dadúpúr; ('Palæontological memoirs', Vol. I page 149) these teeth have apparently been lost; but a drawing is given in the memoir quoted: no other specimens of the genus have ever been recorded. The molar teeth indicate an animal of the hippopotamus family.

In the present season Mr. Theobald has sent down from the Siwaliks of Asnot in the Potwar district a portion of a right mandible of a Hippopotamoid, containing the first and second molar teeth, and the ultimate premolar, together with the penultimate premolars of both sides of the jaw. The molar teeth of this specimen seem to correspond in general character with the molars of Falconer's *Tetraconodon* so closely, that I have referred the present specimen to the same genus and species.

The second molar tooth has not yet come into full wear, and is in excellent state for description. The crown of this tooth is oblong in shape; it is produced at its angles into four conical or mastoid processes, forming a pair at each end. A cruciform valley occupies the surface of the crown between the four cones; the transverse portion of this valley is the widest and deepest; the extremities of this transverse valley extend downwards to the sides of the crown. At the central hollow between the four cones there is a bilobed flat tubercle; another talon tubercle occupies the hindmost portion of the antero-posterior valley; there is a very small tubercle at the outer extremity of the transverse valley. There is no cingulum.

On the worn surface of the first molar the plane of wear slopes very slightly outwards.

The resemblance between this penultimate lower molar and the penultimate upper molar of Falconer's specimen (as may be seen by comparing the two descriptions) is complete; and on the evidence of this tooth alone I have united the two specimens under one species.

I now come to the premolar teeth of my specimen, hitherto unknown, and which are of a most abnormal and interesting character. These teeth vastly exceed in size the true molars, a character which is, I believe, unknown among other mammals; they are placed in direct contact with the molar series, and have a general resemblance in form to those of *Hippopotamus* and *Merycopotamus*; each is inserted into the jaw by two fangs; the penultimate premolar does not present any facet of pressure on its anterior surface, and was therefore probably separated by a diastema from the preceding tooth.

The ultimate premolar has a nearly square base, from which rises an oblique compressed cone, the summit being directed backwards and placed a little in advance of the hindmost border of the crown; the anterior face of the cone projects into a sharp sinuous ridge running from summit nearly to base, expanding below into a cingulum, which occupies the greater part of the anterior base; the cingulum slopes from the ridge to the antero-external angle. A small tubercle occurs between the summit of the cone and the posterior border; this tubercle forms the summit of another cingulum occupying the posterior surface; the posterior cingulum slopes towards the base of the crown on each side from this central point; the outer extremity of the cingulum forming a very marked ledge at the postero-external angle of the crown; a rounded notch occupies each side of the crown between the roots of the fang. The inner surface of the tooth is nearly vertical, the outer sloping.

The enamel is arranged in irregular branching ridges radiating from the summit to the periphery of the base; these ridges are again marked by fine parallel transverse striæ.

The summit of the crown is worn obliquely, the face directed upwards and backwards; the worn surface present two facets, and is of an irregular oval shape, the longer diameter placed antero-posteriorly.

The penultimate premolar differs from the other in being rather smaller in the base of the crown presenting a somewhat triangular cross-section, and in the summit of the cone being more directly over the centre of the crown. A more prominent ridge from this summit runs along the centre of both anterior and posterior surfaces; the posterior cingulum is also rather more prominent.

The dimensions of the specimen are as follows, in inches and tenths:—

Length of two molars ...	2·50
Ditto 2nd molar ...	1·45
Width of ditto ditto ...	1·30
Height of ditto ditto ...	·80
Length of ultimate premolar ...	2·15
Width of ditto ...	2·10
Height of ditto ...	1·80
Length of penultimate premolar...	2·05
Width of ditto ...	1·80
Height of ditto ...	1·65
Depth of jaw at ultimate premolar ...	3·10
Length of the penultimate molar of Falconer's specimen ...	1·40

The general form of the premolars resembles those of *Hippopotamus*: the cingulum, however, is confined to the fore and aft surfaces only. In the position of the cingulum, and in the straightness of the inner wall of the premolars, the specimen approaches the premolars of *Merycopotamus*.

As stated by Falconer, the molars can only be compared with those of *Hippopotamus* and its allies; the position of the four cones at the corners, and the absence of the trefoil-shaped surface of wear, sufficiently distinguishes the molars from those of *Hippopotamus*. From *Sus* they are distinguished by the slight degree of obliquity of the worn surface, and from the crown surface not being a collection of semi-distinct tubercles, but divided into four distinct simple cones. The cruciform valley is a character common to this genus and *Sus*.

The distinction between the molars of this genus and *Anthracotherium* are well pointed out by Falconer in his memoir.

The peculiar form and size of the premolars, now first known, (sufficiently differentiate this) remarkable genus from all its congeners. The gigantic size of the premolars appears to be a further extension of the ultra development of the anterior teeth, which is found in *Hippopotamus* and *Sus*: in the living genera this ultra development is confined to the canines and incisors only, while in the fossil genus it extended back to the premolars. It is to be hoped that further researches may bring to light the cranium and anterior teeth of this most remarkable mammalian form.

The genus was called by Falconer by the two names of *Tetraconodon* and *Chærotherium*. The latter name is now applied to a small suine animal from Sausans, (Lar); (see Ann. Mag. Nat. Hist. Ser. IV, Vol. XII, p. 177). For this reason I have here called the genus by its forme name only.

VISHNUTHERIUM IRAVADICUM (nov. gen. mihi.)

Genus founded on a portion of a left mandible discovered by Mr. W. T. Blanford in Burma; the specimen contains the first and second true molar teeth. The general form of the molars is like those of *Camelopardalis*, *Sivatherium*, and *Bramatherium*, and the enamel has the same rugose character; the teeth are, however, distinguished from those of either of the above genera by the following characters:—

Along the whole of the external surface of each molar there is a well-marked sinuated cingulum; this extends half way across the posterior and anterior surfaces, where it is very conspicuous: it is produced into a number of cusps on the anterior surface; there is a prominent tubercle at the entrance to the main valley between the barrels: the other characters differ but slightly from those of the teeth of the above genera.

Length of two molars	3·8
Ditto of last ditto	1·45
Breadth of ditto...	1·0

This genus is distinguished from *Sivatherium* and *Bramatherium* by its small size, and by the presence of the cingulum and tubercle; from *Camelopardalis* by the presence of a cingulum, and by the tubercle being pointed and present in both molars, instead of being blunt and only present in the first molar: other minor differences will be noted when the specimen is figured and described fully.

APPENDIX B.

The following is a summary of the new forms added to the Siwalik fauna by the collections brought down during the present year by Mr. Theobald, together with notices of some of the more remarkable and rare specimens of previously known species.

Perhaps the most interesting of these additions is a specimen of the tympanic bone of a species of Cetacean: the specimen presents some points of affinity to the corresponding bone of *Platanista*, and is of about the same size; it, however, presents such differences as will probably necessitate its being placed in a distinct genus. This is the first instance of a Cetacean bone having been obtained from the Siwaliks, though Falconer conjectured that they would eventually be discovered

Two genera, though previously known in other tertiary beds of India, have now been for the first time added to the true Siwalik fauna: these are *Listriodon* and *Aceratherium*.

Of the genus *Bos* and allied forms, four new species have been added to the Siwalik fauna: descriptions of these will shortly be published in the "Palæontologia Indica."

Rhinoceros: a new species of this genus, founded on upper molar teeth, has also been obtained.

Tetraconodon magnum, hitherto known by the drawing only of the Dadúpúr specimen, is represented by the jaw noticed above.

Lutra: a portion of a lower jaw, which seems to be larger than *Lutra palæindica*, and may perhaps be distinct.

Bramatherium.—Of this genus we have obtained a very perfect cranium, not yet cleaned from its matrix; the teeth are complete, and the cranium seems only lacking the horn-cores to be also complete: this is, I believe, the first perfect cranium discovered.

Dorcatherium sp.—A number of molar teeth and jaws; the upper molars indicate the existence of two species.

Camelopardalis sivalensis.—Part of a lower jaw, and two upper molars.

Merycopotamus sivalensis.—Several portions of lower jaws, and an astragalus.

Ursitaxus sivalensis.—The first true molar, and the last premolar from the maxilla of each side; these teeth are valuable additions to our collection, as the genus has been hitherto known only by Falconer's two specimens: the one a cranium, and the other a fragment of a lower jaw.

Hyæna sivalensis.—Several fragments of lower jaws.

Felis sp.—One lower carnassial tooth.

Ursus n. sp. cranium.

In addition to the Mammalian specimens, I have also to notice the discovery of a very perfect cervical vertebra of a bird belonging to the order *Grallatores*. Falconer also had one or more specimens of bird-bones, which he referred to the same order; and it is not improbable that our new specimen may be closely allied to Falconer's. Falconer considered that his specimens belonged to a bird which must have exceeded in size the gigantic Bengal adjutant *Leptoptilus argala*.

Remains of Ophidians have not hitherto been recorded from the Tertiary Faunæ of India; it is therefore interesting to have to notice their discovery from two localities in the present year. Mr. Theobald has brought four dorsal vertebræ of a species of snake allied to, but smaller than, the Indian Python from the Siwaliks of the Potwar district; while Mr. Fedden has collected two very similar vertebræ from the Siwaliks of Sind.

I shall hope on a future occasion to give descriptions and figures of the more remarkable of these novelties.

Note on Camelopardalis from the Siwaliks. In looking over the collection of ruminant teeth from the Siwaliks in the Indian Museum, the great rarity of the teeth of this genus struck me as being very remarkable, especially as Falconer had determined two species, *viz.*, *Camelopardalis affinis* and *Camelopardalis sivalensis*. The former of these species was founded upon molars closely resembling those of the living African species, while the latter was founded upon a cervical vertebra. (The specimens are figured in the "Palæontological Memoirs," Vol. I, p. 198.)

It then occurred to me to consider why separate species had been made from these two series of remains, which on *primâ facie* grounds it would have seemed natural to refer to one species. I then found that in the catalogue of the Fossil Mammalia of the Asiatic Society of Bengal, there were certain teeth which had been entered by Dr. Falconer as the lower molars of the second species of *Camelopardalis* (*C. sivalensis*). These teeth are numbered in the collection $\frac{S.}{550}$ and $\frac{S.}{551}$; on examining these specimens I was greatly surprized to find that they belonged to *Bos* or some allied form, and not to *Camelopardalis* at all. (The teeth are much narrower in proportion to their length than in *Camelopardalis*; they have a long slender accessory lobe between the two cylinders, which reaches to the summit of the crown, whereas in *Camelopardalis* there is only a minute tubercle at the base of the cylinders; and finally the outer walls of the cylinders are placed nearly parallel to the long axes of the teeth, instead of very obliquely, as in *Camelopardalis*). These

teeth have a somewhat rugose enamel, and I can only suppose that in a hasty examination Dr. Falconer, who says that at the time of cataloguing them he had no means of making a comparison at hand, was led away by this character into placing them under the head of *Camelopardalis*.

No teeth have therefore been found which are referable to *Camelopardalis sivalensis*; on turning to Dr. Falconer's remarks upon the genus, it is stated that the teeth figured in the "Palæontological Memoirs" were assigned to a second species, because they were of too large a size to have belonged to an animal possessing cervical vertebræ of the size of those of the original *Camelopardalis sivalensis*.

On turning to the measurements of the vertebra of the latter species ("Palæontological Memoirs," Vol. I, p. 201), I find that the specimen was described as being one-third shorter than the corresponding vertebra of the living species; but on looking at the relative dimensions of the centre of the vertebra of the two species, I find very small differences between them; indeed, some of the diameters of the vertebra of *C. sivalensis* are actually larger than those of *C. giraffa*.

The following measurements are taken from Falconer's table:—

	C. sivalensis.	*C. giraffa.*
Vertical diameter of anterior articulating surface of centrum ...	1·9	1·55
Transverse ditto ditto ...	1·4	1·6
Length of post-zygapophysis	1·6	1·2
Width of disc.	1·0	0·8
Length of pre-zygapophysis	1·2	0·85
Vertical diameter of posterior articulating cup of centrum ...	2·0	2·2

From the above measurements it will be seen that the anterior articulating ball of the centrum has an area nearly equal in the two species; the diameter of the posterior cup of the vertebra of the recent species is rather the larger of the two, but this is caused by a less development of the rim in the fossil specimen. Both of the zygapophyses present a considerably larger area in the fossil than in the recent specimen; and since their surfaces are the main aids in connecting the different vertebra, it is clear that the neck of the fossil species was at the least equally strong with that of the living species, and was therefore capable of supporting a head and teeth as large as those of the latter.

Moreover, from its shortness and consequent absence of the great leverage which occurs in the living species, the neck of the fossil species might well bear even a still larger head and teeth than those of the living species.

From the above arguments I am perfectly convinced that Falconer's second species—*Camelopardalis affinis*—founded upon the teeth alone, should be abolished, and both teeth and vertebra assigned to *Camelopardalis sivalensis*.

Camelopardalis sivalensis, according to this view, was an animal furnished with molar teeth (and probably with a cranium) of the same size as those of the living *Camelopardalis giraffa*; its neck, however, was one-third shorter than that of the latter; it probably took its origin from some short-necked form allied to *Sivatherium*; while the long neck of the recent species is, as we should naturally expect, a specialized character of quite modern origin.

As according to the above view we have only one species of Siwalik giraffe, the rarity of the molars, though still very remarkble, is not so noticeable as if there had been two species.

Note on Merycopotamus.

M. Nanus, Falc. This species was added to the list of Indian Fossil Mammalia by Dr. Falconer on the evidence of several molar teeth and one premolar from Kushalghar near Attock ("Palæontological Memoirs," Vol. I, p. 416).

Lately, on looking over the collection containing these specimens, I was surprised to find that the molar teeth ascribed to this species do not really belong to the genus *Merycopotamus* at all, but to the genus *Dorcatherium*: (on a hasty examination it would be possible to mistake the one or the other.)

The premolar tooth does, however, belong to *Merycopotamus*, and seems to be quite of the same form and size as the corresponding tooth of *Merycopotamus dissimilis*.

It will therefore be necessary to remove this new species of *Merycopotamus* from the list of Attock fossils, as given by Falconer, since it is founded only on the above-mentioned molars. I shall figure these teeth of *Dorcatherium* in a subsequent paper on Siwalik Ruminants

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P. S.—Since writing the above I have to add an Edentate allied to Manis, but larger, to the Sind fossil Fauna; the specimen consists of a phalange of the third digit of the manus.

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F. V. HAYDEN, Esq.

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GEOLOGICAL SURVEY OFFICE,
3rd July 1876.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1876. [February.

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1875.

The close of another year brings with it the duty of reporting briefly the progress made during the past twelve months. As must almost necessarily be the case in such a department as the Geological Survey of India, the full number of the officers in the establishment has never actually been at work during the year; while even of those present and actively engaged, some have had their time almost fully occupied with subjects, not immediately forming a part of the Survey operations, although intimately connected with them.

In this way, Mr. W. T. Blanford was very fully occupied in the examination and description of the zoological collections collected in Yarkand by the late Dr. Stoliczka, and in arranging for publication the geological notes of the same trip. Mr. F. R. Mallet was absent on three months' leave, Mr. Hacket was absent on furlough till within a couple of months of the close of the year, and Dr. W. Waagen, who had only returned from Europe at the beginning of the season, was obliged again to leave India, and, to our great regret, and the very serious loss of the Survey, felt compelled to resign all hopes of returning.

Mr. Medlicott's labours in the earlier part of the year were confined to the coal-fields in the Satpura hills. Full notes of his researches have been already published, so that it is unnecessary to enter into any detail here. One important fact may be noticed. Towards the close of the season, Mr. Medlicott was fortunate enough to notice the occurrence of rocks, which he considers as undoubtedly representative of the upper part of the series accompanying the coal-bearing rocks elsewhere, at a point much further to the west than these had been known previously to occur. And he justly bases on the occurrence of these rocks a recommendation for further detailed search in the district, and suggests the propriety, seeing [illegible] vast importance of a supply of coal in that neighbourhood, of borings to test the [illegible] any such deposits. It would be essential that such borings, if attempted, should be [illegible] a very considerable depth, before any definite reply to the question of the existence [illegible] could be obtained. And in estimating the value of the chances, it will be essential to re-member, as Mr. Medlicott himself remarks, that even if the coal deposits should be proved, it is impossible to make even a probable guess, as to the depth beneath the surface at which they are likely to lie, "2,000 is as likely as 500 feet."

Unless coal should be found in very consi[illegible] and most favorably as to dip, &c., I need scarcely say that mining [illegible] of [illegible] feet would be a [illegible]

of such difficulty, danger and cost in this country, that it certainly would not pay for many years to come, if ever, while even on general considerations, some of which have been partially explained before now, and have been confirmed by everything since noticed, I am not at all sanguine that any favorable deposits of coal will ever be found in the area indicated.

The geological facts noticed by Mr. Medlicott are of the highest interest as regards the structure of the valley of the Nerbada, and his suggestions must not be lost sight of in future investigations.

Up to date, no very definite results have been obtained by the borings now in progress at Toondnee and Khappa, but neither has any proof been obtained that the rods have reached beds below the coal-bearing rocks.

Mr. Medlicott, at the close of the season in the early part of the year, took advantage of an invitation to visit Khatmandu in Nepal, and a very interesting and suggestive notice of this visit is given by Mr. Medlicott in the Records of the Geological Survey of India for November last. It must always be a source of great regret that the movements of Europeans are so jealously watched in Nepal, that it is impossible to do more than pay a hurried visit to the localities immediately round the capital, or the places actually on or adjoining the road there and back. Mr. Medlicott saw, perhaps, everything that he could have seen, that is, that he would have been permitted to see, but this was barely sufficient to suggest a few possibilities as to the structure of the adjoining country, the correctness or incorrectness of which could not be established by further research. The continuity of the zone of newer rocks which fringes the Himalayan range to the north-west has been established, and the occurrence of the newer tertiary groups also proved.

At the commencement of the present working season, Mr. Medlicott, in conjunction with Mr. Theobald and Mr. Lydekker, commenced a revision of the tertiary rocks of the North-West and Punjab. The very important fact of a marked stratigraphical separation of two distinct groups of rocks in the Nahun country, which had previously been all considered as a continuous series of beds, was first noticed by Mr. Medlicott himself. The locality where this marked unconformity was noticed unfortunately did not yield any fossils from the lower group of the rocks, so that the very important question as to whether this marked separation of the rocks physically was accompanied by any distinction in their organic contents was still undecided. To determine this, it became necessary to trace the same two groups further to the north-west, and to collect the fossils from each group separately. In doing this, it became evident that the very marked unconformity noticed in the Markunda river did not continue to the north-west. And the separation of the groups must obviously be based on other considerations. Apparent distinctness in the fossils also on more careful examination disappeared, if not entirely, nearly so. It became, therefore, of the last importance that the separation of these groups should be more carefully investigated, and their relations one to the other established. And with this object in view, I requested Mr. Medlicott to go carefully over the entire ground again, giving him the aid of Mr. Theobald, who knew the fossil localities tolerably well, and had already brought together a very valuable collection from these rocks, and also the help of Mr. Lydekker, who had been all the previous part engaged in a careful and earnest examination of the fossils, on which he had throw much light. And I confidently hope that before the season closes, the these tertiary groups may be demarcated and their relations established.

considered with reference to a study of the tertiary rocks of ledge of the structure of Sind has long been patent. It has been more

than once intended to take up the examination of that province. In 1869, arrangements were made for doing so, but other and more pressing demands caused this to be laid aside. Again in 1871, the same thing occurred, to our great regret. The sections in Sind were known to be unusually clear and well exposed; many of the rocks were richly fossiliferous, and while a very large number of species had been already collected and described, it had become evident that they had been erroneously referred all to the same series. It was also highly probable, if not certain, that we should in Sind find a connecting link between the tertiaries of Cutch and of the Sub-Himalayas. It was therefore with great satisfaction that we were able at last to depute Mr. Blanford, with the aid of Mr. Fedden, to take up Sind in 1874. Before the close of the working season of 1874-75, they had completed a fair sketch of the geology of the province, and have again this year resumed their labours there, Mr. Blanford also purposing to accomplish a traverse of the desert to Jessulmir and Jodhpur, and so probably back again by a different route to Sind. Mr. Fedden also has been able to bring together a very good collection of fossils, some of them very beautifully preserved.

During the summer, Mr. Blanford was, as already stated, chiefly occupied in working out the collections of Dr. Stoliczka from Yarkand preparatory to publication, but continued to superintend Mr. Fedden while he was carefully comparing the numerous collections brought from Sind, he himself taking up the Echinoderms, while Mr. Fedden confined his labours to the Mollusca. There was no time to investigate the Corals. A full sketch of the geological results is given in the present number of the Records of the Geological Survey of India, so that it is only necessary to mention briefly, here, that Mr. Blanford seems to have established the existence, in addition to the more recent and subrecent deposits, of rocks of pliocene, miocene, and eocene age, all of which had previously been roughly grouped into old tertiary. While in places there are still lower beds, the exact geological age of which is not fixed, but which are, in part at least, probably cretaceous.

Mr. Fedden has worked very earnestly and intelligently, and to Mr. Blanford's satisfaction, and by his careful study of the fossils collected last season, has acquired a knowledge of their forms and distribution, which will prove of very essential advantage to him during the present season in examining the continuation of the same rocks.

Mr. Willson has very steadily continued his work in the Bundelcund and Rewah country, and has mapped in several sheets of the new topographical survey, during the progress of which work, some important geological facts have been established.

Mr. Hacket only returned from leave of absence in Europe in time to take the field a little later in the season than usual in Rajpootana. Since then he has been actively engaged in Ulwar, and it is hoped that by the close of the working season, he will have completed a general geological sketch of that district.

During the entire season, Mr. Hughes was engaged in finishing up the geological maps of the Chanda country, with more especial view to the coal-fields of the Wardah valley. A report on these has since been completed, after most unlooked for delay, and is now gone to press. Mr. Hughes, during the present season, has taken up the continuation of same geological area to the south, and will, it is hoped, be able to join on his work to that of Mr. King, who is extending his examination from the south up the valley of the Godavery.

Mr. Ball completed the examination of the Raigarh and Hingir coal-field, on which he had been engaged during the previous season. Of this field, an interesting sketch is

given by Mr. Ball, and published in the Records. During the present working season, Mr. Ball has been engaged in a revision of the Talchir coal-field, and in an examination of the Atgurh sandstones.

Dr. Feistmantel, who joined the Survey at the commencement of the year, has been most earnest and zealous in working out the fossil plants of the several groups of rocks in India, and has already accumulated much valuable matter. He has commenced the preparation of a history of the fossil flora of Kachh, which, taken in connection with the already published descriptions of some of the fossils from the associated beds, will prove of great interest and value. There is little doubt that the fuller and more careful investigation of the several floras from the successive groups of rocks will throw much light on the relation of the different members of what it has become a fashion to style the plant-bearing series.

In Madras Presidency, Mr. King completed the examination of the Rajahmundry country before leaving the field. I regret to have to report that exposure to the first burst of the monsoon before reaching station resulted in a very severe attack of inflammation of the eyes, which for some time assumed a very serious form. Fortunately this was conquered, and Mr. King's sight saved, although his recovery was tedious. Taking the field again at the commencement of the season he has visited the several fields near the lower valley of the Godavery, and closed up that part of the area, and has since proceeded northwards along the Godavery valley, with a view to joining Mr. Hughes, who has been carrying out the examination of the same valley proceeding southwards.

Mr. Foote succeeded in mapping in a good area of the country along the coast in the Nellore and Ongole country, and was fortunate also in finding some very beautifully preserved and interesting fossils of Rajmahal age. And in the present season he continues the same work northwards, with a view to join on to the Godavery and Rajahmundry areas. During the recess, Mr. Foote completed a valuable report on the Southern Mahratta Country, which is now in hands preparatory to going to press.

Publications.—Of the MEMOIRS of the GEOLOGICAL SURVEY OF INDIA, Vol. XI, Pt. 2, containing a detailed description of the salt-producing country in the Kohat district, Trans-Indus, was issued. The illustrations required for this part occupied some time, and the absence in Europe of the writer, Mr. Wynne, also involved some delay in reference in a few points.

Of the RECORDS of the Survey, the regular quarterly issue was punctually maintained, and the volume for the year will be found to contain several very valuable papers on the geological structure of various parts of India. "The paper on the Altum Artush, from a geological point of view," by the late Dr. F. Stoliczka, completed the series of short papers bearing on his trip to Yarkand, which he had left ready for publication. Among other descriptive papers, we have a note on the geology of Nepal by Mr. Medlicott, on the Kharesan Hills in the Punjab by Mr. Wynne, a sketch of the geology of Scindia's territories by Mr. Medlicott, and a full sketch of the Shapur coal-fields, with notices on the explorations in progress in the Nerbada valley for coal: also an account of the Raigarh and Hingir coal-field by Mr. Ball, while the practical bearings of geological research are illustrated by Mr. W. Blanford's paper on the water-bearing strata of Surat, Mr. Hughes and Mr. [illegible] on fire bricks, Mr. Mallet on coal near Moflong, &c.

[illegible]ONTOLOGIA INDICA, the publication of the Jurassic Cephalopoda from [illegible] continued. The whole series is now completed and issued, although the

difficulties caused by the preparation of such a large number of plates delayed this completion beyond the actual close of the past year. This series contains 60 plates, of which six are double, and 250 pages of letter press, with explanations of plates, &c., and is unquestionably one of the most valuable contributions to the fossil history of the Upper Jurassic Cephalopoda ever yet issued. This was all completed, though not printed off, when Dr. W. Waagen felt compelled to resign his connection with the Geological Survey of India. A great source of delay in the completion of the plates has arisen from the transfer of our offices to the New Museum, and the time, unavoidably lost, in moving and re-setting up the lithographic presses.

Good progress has also been made in the preparation of plates for the next issue of the Palæontologia Indica which will be devoted to the fossil flora of Kachh. It was hoped that we should have been able to continue the same detailed illustrations of the fossil mollusca in the other groups, as have now been published of the Cephalopoda. But the loss of our Palæontologist has for the present deprived us of the means of accomplishing this.

It will be seen that there have been issued during the year no less than 55 plates, equivalent, from double ones, to 61 of the regular quarto size, the annual number promised being only 48 (originally 24).

Library.—During the twelve months of 1875, 881 volumes or parts of volumes have been added to the Library of the Geological Survey. Of this number, 437 have been received from Societies and other Institutions in exchange for the publications of the Survey, or as donations, and 444 have been purchased. Quarterly lists of these additions have been regularly published as usual in the Records, and a nominal list of Societies and Institutions from which presentations or exchanges have been received is appended.

The removal of so large and valuable a series of books to the new offices of the Survey was a task of some risk and trouble, especially during the rains, but it was effected with but little injury. The greater space we have now at disposal has already admitted of a fuller and more detailed classificatory arrangement of the books than was previously possible. The completion of this arrangement will, however, necessarily occupy some time, and cannot be altogether satisfactorily accomplished until after the completion of the proposed gallery and another series of cases.

The Library continues to be a great resource to students, who can obtain access here to books, many of which do not exist in any other collection in Calcutta, or indeed in India.

Museum.—The removal of all the collections from the former offices of the Geological Survey to the new Museum was a task of no small trouble and labour, as well as risk. It could not have been expected that such a series could be moved without some injury to the more delicate fossils, and to the numerous casts of unique animals which our collection contains, nor was this danger diminished by the fact that the greater part of the removal was effected during the rains. It has consequently taken some time to restore all these things to their proper condition. With regard to the rearrangements of the full collections, inasmuch as no additional cases have as yet been provided for exhibition, we have been compelled for the present to content ourselves with merely grouping the collections and thus rendering them more easily accessible for the final arrangement when cases are available. Orders have been given for a considerable number already, and it is hoped that some will soon be ready.

The want of any out-offices has also compelled us to interfere seriously with the proper arrangement of the Museum by necessitating the storing away of tents, boxes with specimens, and other stores in the galleries of the Museum.

The collections are all in good order and preservation.

T. OLDHAM,
Supdt., Geological Survey of India,
and Director of Geological Museum.

CALCUTTA,
February 1876.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1875.

BATAVIA.—Royal Society of Batavia.
BERLIN.—German Geological Society.
" Prussian Academy of Sciences.
" Gesellschaft fur Erd Kunde.
BOMBAY.—Bombay Branch of Royal Asiatic Society.
BONN.—Naturhistorisches Vereins.
BOSTON.—Museum of Comparative Zoology.
" Boston Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Naturalists' Society of—
BRUSSELS.—Royal Academy of Sciences.
BUFFALO.—Buffalo Society of Natural Sciences.
CALCUTTA.—Asiatic Society of Bengal.
" Agricultural and Horticultural Society.
CAMBRIDGE, MASS., U. S., A.—United States Coast Survey.
CHRISTIANIA.—Royal University of Norway.
COPENHAGEN.—Royal Danish Academy.
DIJON.—Academy of Sciences, Dijon.
DRESDEN.—The Isis Society.
" The Leopoldino Carolino Academy of Naturalists.
" The Royal Museum.
DUBLIN.—The Royal Irish Academy.
" Royal Geological Society of Ireland.
EDINBURGH.—Geological Society of Edinburgh.
" —Royal Society of Edinburgh.
GENEVA.—Physical and Natural History Society of Geneva.
GLASGOW.—Philosophical Society of Glasgow.
" Geological Society of Glasgow.
GÖTTINGEN.—Royal Society of Science.
LAUSANNE.—Vandois Society of Natural Science.
LIEGE.—Geological Society of Belgium.
LIVERPOOL.—Literary and Philosophical Society.
" Geological Society.

LONDON.—East Indian Association.
" Royal Geographical Society.
" Royal Society.
" Geological Society of London.
" Anthropological Institute.
" Royal Institution.
" British Museum.
" Linnæan Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Geological Survey of Victoria.
" Mining Department, Victoria.
" Royal Society of Victoria.
MINNESOTA.—Academy of Science.
" Geological Survey of Minnesota.
MOSCOW.—Imperial Society of Naturalists.
MÜNICH.—Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Science at Neuchatel.
NEW HAVEN.—American Journal of Science.
NEW ZEALAND.—Colonial Museum and Laboratory.
" Wellington. New Zealand Institute.
PARIS.—L'administration des Mines.
" Geological Society of France.
PESTH.—Royal Hungarian Geological Institute.
PHILADELPHIA.—Franklin Institute.
PLYMOUTH.—Devonshire Association.
ROME.—Geological Commission of Italy.
ROORKEE.—Civil Engineering College.
SALEM, MASS., U. S., A.—American Association for the advancement of Science.
" Essex Institute.
STOCKHOLM.—Bureau de la recherche Geologique du Suede.
ST. PETERSBURG.—Imperial Academy of Sciences.
SYDNEY.—Royal Society of New South Wales.
TORONTO.—Canadian Institute.
VIENNA.—Imperial Academy of Sciences.
" K. K. Geologische Reichs-anstalt.
" Zoologico-Botanical Society.
WASHINGTON.—Smithsonian Institute.
YOKOHAMA.—German Naturalists' Society.
ZÜRICH.—Swiss Palæontological Society.
" Swiss Natural History Society.

Governments of India, Madras, North-Western Provinces, Punjab, and Bombay, Chief Commissioners of British Burmah, Central Provinces, Surveyor General of India, Superintendent of the Great Trigonometrical Survey of India, and the Superintendent of the Thomason College, Roorkee.

On the Geology of Sind. By William T. Blanford, A.R.S.M., F.R.S., *Deputy Superintendent, Geological Survey of India.*

Introduction.—It has been for many years past an object of the last importance in making out the relations of the tertiary rocks of India to examine the geology of the province of Sind, and, but for the pressure of other work, the examination of that country would have been undertaken before. I was directed by the Superintendent of the Geological Survey on two previous occasions, in 1869 and 1871, to commence the survey of Sind, but other and more pressing work in each case interfered. During the working season 1874-75, a general examination of the province was made by my colleague, Mr. Fedden, and myself, the principal results of which are given in the following pages. The area of which a preliminary survey and sketch map were made exceeds 9,000 square miles, exclusive of the alluvial area. The survey is still in progress, and all recent observations tend to confirm the classification proposed.

A very large share of the work both in the field, and subsequently in the determination of the fossils, was done by Mr. Fedden, and the knowledge gained of the geology is quite as much due to his observations as to my own.

The importance of a thorough geological examination of Sind is due to two circumstances. *First*, it has long been known that there is in that province a fine series of tertiary rocks abounding in fossils. *Secondly*, the magnificent figures and descriptions of the Indian nummulitic fossils by Messrs. D'Archiac and Haime in their "Description des Animaux fossiles du groupe Nummulitique de l'Inde" published in 1853, probably the most important single contribution to Indian Geology ever issued in Europe, lose half their value from the circumstance that the exact position in the series of the beds from which the different fossils described were obtained was unknown. The majority of the fossils had been procured in Sind, but the exact localities were not recorded.

Physical geography.—The province of Sind consists geographically of the Indus valley and of the hill ranges to the west of the river, from the neighbourhood of Kashmor and Jacobabad, or the latitude of about 28° 30′, to the sea.

The whole province is generally divided into Upper and Lower Sind. Upper Sind consists of a broad alluvial plain extending for many miles on both banks of the river, but interrupted near Sakhar (Sukkur) and Rohri by a range of limestone hills, isolated in the alluvium and running nearly north and south. These hills are intersected close to their northern extremity by the river which runs at this spot from north-east to south-west, and they extend about fifty miles south of it. Beyond the flat alluvial tract east of the river is an extensive region of sandy desert. To the west of the river the alluvial plain extends to the mountains which form the frontier of the province, and which, under the name of the Khirthar range,* extend from the Bolan pass to considerably south of Sehwán. There is only one break in this range, that formed by the Gáj river, and the gorge of the stream is quite impassable; everywhere else the range rises to heights varying from about 3,000 to over 7,000 feet.

In Lower Sind the alluvial plain is almost confined to the left or east bank of the river, and between the Indus and the western frontier of the province the country is hilly. On

* [illegible] this and some other ranges were united under the name of the Hala range, but no such [illegible] in the province. By Vicary the term Hala-range was applied loosely to several distinct ranges, [illegible] of the period, he evidently supposed to be portions of the same, and the name has [illegible] commonly in works referring to the Geology of Sind. The result, as regards all attempts to [illegible] localities, is most confusing.

the east of the river there is an isolated low range of limestone hills near Hyderabad, and another near Tatta. The country west of the river consists partly of an undulating plain, partly of ranges of hills formed of limestone, and having a general north and south strike. The highest of these ridges are met with south and south-west of Sehwán: towards Kotri, Tatta and Karachi only low hills or undulating plains are found.

Geological formations.—Within the area of Sind no rocks have as yet been detected containing fossils of older date than Eocene, but the lowest rocks hitherto found in the province are unfossiliferous, or contain only a few vegetable remains which are not well preserved. From Dr. Cook's researches in Kelat, we know that mesozoic rocks with *Ammonites* are found in that direction, and at no great distance from our frontier; whilst from the Khirthar range close to the Gáj river, I saw lower beds cropping out from below the eocene limestone.

The result of the researches of the past year is that the following formations, in descending sequence, have been detected in Sind:—

Name of group.	Approximate age.	Character of rocks.
Superficial beds, alluvium, &c. ...	Subrecent and recent ...	Blown sand. Alluvium of the Indus, both of the river plain and the delta. Slopes and deposits of gravel, often consolidated.
Manchhar or Sevalik ...	Pliocene	(*a*) Massive conglomerate on the edge of the alluvial plain; (*b*) clays, sandstones, and conglomerates, usually unfossiliferous, but sometimes containing bones.
Gáj or Supra-nummulitic ...	Miocene	Highly fossiliferous marine limestones, clays and sandstones, usually in thin beds; no nummulites.
4. *Nari* or Upper Nummulitic ...	Lower miocene or upper eocene	(*a*) Sandstones, very massive and of great thickness, sometimes variegated; unfossiliferous, but interstratified towards the base with (*b*) yellow and brown limestones with *Nummulites garansensis*, *N. sublævigatus*, and *Orbitoides papyracea*.
3. *Khirthar* or Lower Nummulitic	Eocene	(*a*) Massive, white and grey limestones with many species of *Nummulites*, *Alveolina*, &c. (*b*) Highly fossiliferous yellow limestone with *Operculina canalifera*, &c. (local). (*c*) Green clays of Rohri and Hyderabad.
2. *Ranikot* or Infra-nummulitic	? Lower eocene	Shales and sandstones, in part variegated and richly colored, thinly bedded, containing only vegetable remains.
1. Volcanic	?	Basalt.

The new names proposed are all taken from well known localities in Sind. *Manchhar* is from the Manchhar Lake, on the southern and south-western banks of which the Sind representatives of the Sevaliks are well seen. *Gáj* is the name of a river which traverses the frontier range north-west of Sehwán, and exposes a superb section of the middle tertiary deposits. The name applied to the Upper Nummulitics is taken from the Nari Nai, a stream which drains the hills a little way south of the Gáj, and the upper course of which lies almost entirely amongst the formations named from it; whilst the Khirthar range, dividing the whole of Upper Sind from Kelat, gives its name to the great mass of Lower Nummulitic limestone, of which its higher ranges are entirely composed. The term proposed for the Infra-nummulitic group is taken from the stronghold of the Sind Amirs in the range north-west of Kotri. It appears to me better in every case to apply a local

name than to use exclusively terms derived from European Geology, which may subsequently have to be abandoned, or to adopt names from other areas in India the rocks of which have not been distinctly correlated with those of Sind. There is, for instance, but little reason to doubt that the Manchhar group of Sind represents generally the Sevalik and Nahun beds of the Punjab; but still there is a question as to whether it corresponds only to one of those groups, or whether both are represented.*

It should not be forgotten that Messrs. D'Archiac and Haime had actually foretold† from their examination of the fossils the division of the Sind Nummulitics into two groups, an upper division with *Nummulites garansensis*, and a lower with *N. Ramondi*, *N Leymeriei*, *N. granulosa*, *N. exponens*, *Alveolina ovoidea*, &c., and they also correctly indicated the existence of a third sub-division without Nummulites. But here the clue afforded by the Foraminifera failed them, for there are beds without nummulites at the extreme base of the series, and others at the top, and it was, of course, impossible for them to tell from which part of the series their fossils had been derived, except so far as the alliance to European forms guided them.

Subsequently it was shown by Professor Martin Duncan (Annals and Magazine, Natural History, Ser. 3rd, Volume XIII, p. 295), and by Mr. Jenkins (Quarterly Journal Geological Society, Lond., Vol. XX, p. 45), that many of the Sind fossils, and especially some corals which had not been described by Messrs. D'Archiac and Haime, were unmistakably of miocene age.

The rocks of Captain Vicary's classification,‡ to which allusion has so often been made in geological works, are the following, with their equivalents in the system now proposed:—

Groups of Captain Vicary.	Groups now proposed.
1. Conglomerate §	Manchhar (Sevalik).
2. Clays and sandstone	
3. Upper bone bed	
4. Sandstone; fossils rare	
5. Lower bone bed	
6. Coarse, arenaceous, calcareous rock with *Cytherea exoleta*,‖ and *[illegible]arata*, *Spatangi*: no Nummulites	Gaj (Miocene).
7. Pale arenaceous limestone with *Hypponices*, *Nummulites*, and *Charoideæ*	Nari (Upper Nummulitic).
8. Nummulitic limestone of the Hala Range	Khirthar, Lower Nummulitic.
9. Black slates: thickness unknown	?

* During the past recess season, owing to a number of other demands upon my time, it has been impossible for me to investigate the relations of the Sind tertiary fauna as I could have wished, whilst, owing to the sad events which have deprived the Survey of its two Palæontologists successively, I have not had the advantage of aid from those better qualified than myself to determine palæontological questions. Under these circumstances, Mr. Fedden undertook the examination of the fossils collected, with such aid as I could give him; and although I believe that most of the identifications mentioned in the subsequent pages are trustworthy, I do not venture to hope that they are free from error. The *Echinodermata* and *Foraminifera* were examined chiefly by myself, the Mollusca by Mr. Fedden. Time did not permit of the corals being examined.

† Descr. An. Foss. du Groupe Num. de l'Inde, p. [illegible]59.

‡ [illegible] Journal Geological Society, Volume III, p. 334.

§ [illegible] coarse [illegible] of the series.

‖ [illegible] Vicary's fossil names have never been clearly identified. His *Spatangi* may have been *Breynia* [illegible] *Jacquemonti*, &c.; his *Hypponices* I have been unable to trace. It is just possible they may [illegible].

VOLCANIC ROCKS.

At the base of the section exposed at Ranikot, where the lowest beds found in the province are seen, and again in a similar position, as I learn from Mr. Fedden, north of Ranikot, basalt is seen. The exposure in each case occupies only a few square feet, and is very obscure. Nothing of importance with reference to this rock has been added during the past season to the observations made in 1863,* and it is still uncertain whether the basalt is intrusive or not, and, in the latter case, whether it belongs to the Deccan group of traps. Its relation to the overlying beds in the latter case is remarkably similar to what it is in Kachh.†

2. RANIKOT GROUP OR INFRA-NUMMULITIC.

These beds have already been described in the Memoirs.‡ They consist of sandstones, shales and clays, with gypsum, and are frequently remarkable for their bright and variegated colors. In some places the shales are carbonaceous, and irregular deposits of lignite occur in them, and they frequently contain pyrites and yield alum.

About 1,300 feet of these beds are exposed in Ranikot, between the base of the nummulitic limestone and the small hummock of basalt which forms the lowest of the rocks seen in the section.

The only organic remains observed in the beds themselves are vegetable, being dicotyledonous leaves, stems, &c. But north of Ranikot, Mr. Fedden found some bands of calcareous shale and limestone some distance below the base of the white Nummulitic (Khirthar) limestone and interstratified with sandstones and shales which may belong to the Ranikot group. These bands contain *Cardita Beaumonti, Nautilus Forbesi, N. Labechei,* and a few other fossils. Those above named have Cretaceous affinities. Further examination of the locality is desirable in order to ascertain the extent to which the two groups can be considered as interstratified. It should be noticed that neither *Cardita Beaumonti* nor the species of *Nautilus* have hitherto been obtained by Mr. Fedden or myself at any higher horizon than the extreme base of the Khirthar group.

The Ranikot group is but sparingly exposed in Sind. It is seen at Ranikot itself, and extends for some distance to the north, finally appearing on the outer scarp of the hills. It is also exposed within the range about four miles west of Ranikot, where it occupies a valley about five miles long by a mile broad, and there is a small tract composed of it, around Lainyan south-east of Ranikot and north-west of Kotri. Here, however, the ground is greatly concealed by surface gravels, and much of the area to the westward is occupied by the grey sandstones of the Manchhar (Sevalik) group, which in places so closely resemble some of the sandstones of Ranikot that they cannot easily be distinguished.

3. KHIRTHAR OR LOWER NUMMULITIC GROUP.

This is by far the most important and characteristic group of rocks in Sind, and all the higher hills of the province are composed of it. As usually developed, it consists of an immense thickness of massive grey and white limestone, abounding in Nummulites and other Foraminifera and unbroken by a single band of any other rock. Such is its character from the northern frontier of Sind to Kotri, but to the southward I am informed by Mr. Fedden that the group shows a tendency to break up into distinct beds, the typical hard limestone being interstratified with bands of softer limestones, sandstones, and shales, and in adjoining areas, in Kachh and Baluchistán, the massive white or grey limestone forms but a subordinate portion of the group.

* Mem. Geological Survey of India, Vol. VI, p. 5.

† Mem. Geological Survey of India, Vol. IX, p. 78.

‡ Mem. Geological Survey of India, Vol. VI, p. 4.

At the base of the Nummulitic limestone, fossiliferous beds occur in parts of the province. These beds it appears best for the present to associate with the Khirthar group, although they may ultimately prove worthy of distinction, or it may, as above suggested, prove necessary to class them with the Infra-nummulitic beds of Ranikot.

The most northern locality at which the basement beds of the Nummulitic group appear to be exposed in Sind is on the west side of the hills south of Rohri. Here beds of pale-green gypseous clays are seen, interstratified with a few bands of impure dark limestone and calcareous shale. These beds are fossiliferous, but the only species that has been recognised in them is *Natica longispira,* which appears to have a wide range in time, being found, according to D'Archiac, in the upper eocene beds with *Nummulites garansensis.* Species of *Lucina, Cardium, Leda, Pinna, Cerithium,* and *Rostellaria* also occur.

Similar green clay was observed by Mr. Fedden near Hyderabad, but no good section was found, nor were any fossils detected in it. In neither case was the base of the green clays seen, so that it is impossible to be certain whether they are not a band locally intercalated in the limestones. The latter appears most probable at Hyderabad.

At the base of the thick Nummulitic limestone in the Vero plain north-west of Kotri, and in similar beds on the same horizon near Jhirk (Jerruck) and Tatta, some very fossiliferous yellowish-brown limestone is found, in which the following fossils have been identified:—*

Foraminifera.

Operculina canalifera (very abundant).
O? Tattaensis, Carter.
Nummulites Leymeriei.
N. irregularis.

Echinodermata.

Cidaris Halaensis?
Porocidaris (spines).
Temnopleurus Valenciennesi.
Echinolampas? *sp.* (one very near E. subsimilis).
Eurhodia Morrisi.
Hemiaster digonus.

Brachiopoda.

Terebratula *sp.*

Lamellibranchiata.

Cardita Beaumonti.
Spondylus Rouaulti.

Gasteropoda.

Turritella angulata.
T. assimilis.
Nerita Schmedeliana.
Natica longispira.
Terebellum distortum.
Terebellum plicatum.
T. subbelemnitoideum.
Rostellaria angistoma.
R. Prestwichi.
R. fusoides.

Cephalopoda.

Nautilus subfleuriausianus.
N. Deluci.
N. Labechei.
N. Forbesi.

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* In this and other lists D'Archiac and Haime's names are used. Their genera often differ from those employed by more modern writers, and their specific determinations may, in many cases, require revision; some of their species, for instance, being probably identical with well known living forms.

The Mollusca are only mentioned, as a rule, when they have been determined specifically. All the Echinodermata found are included in the lists, whether they have been identified specifically or not.

The massive Nummulitic limestone itself abounds in fossils, especially *Foraminifera*, but owing to the nature of the rocks and their mode of weathering, their organic contents usually only appear in section on the weathered surface. Corals, *Echinodermata* and *Mollusca* abound, but the latter, as a rule, weather out as casts. The following are some of the most characteristic fossils identified :—

Foraminifera.

Orbitolites sp.
Orbitoides dispansus.
Patellina Cooki.
Alveolina ovoidea and A. spheroidea.
Nummulites obtusa, Ramondi, Biaritzensis, Beaumonti, Vicaryi, exponens, granulosa, spira, and Leymeriei.

Echinodermata.

Echinolampas discoideus.
E. Sindensis.
Eurhodia Calderi.
Conoclypeus pulvinatus?
Amblypygus sp.
Fibularia sp.
Eupatagus avellana.
Schizaster sp.
Brissopsis Sowerbyi?
B. scutiformis.
B. sp.

Lamellibranchiata.

Ostrea vesicularis (O. globosa, Sow.)
Pholadomya halaensis.
Vulsella legumen.

Gasteropoda.

Nerita Schmedeliana (very abundant).
Ovulum Murchisoni and other species.

Crustacea.

Arges Murchisoni (Galenopsis Murchisoni).
Ranina sp.

Amongst the above the most common and characteristic forms are *Orbitoides (dispansus,* Sow.), *Nummulites* of various species, *Alveolina*, and *Nerita Schmedeliana*. Of the age of this group it is unnecessary to say anything, as it is, of course, the same as that of the Nummulitic limestone of Southern Europe, *viz.*, typically eocene.

The thickness of the Khirthar group has not been determined, but, where fully developed in the Khirthar range, it cannot be less than 3,000 feet, and it may be twice as much. To the south, however, the thickness must diminish greatly, and near Jhirk and Tatta it, probably, does not exceed a few hundred feet.

The Nummulitic limestone forms the whole higher portion of the Khirthar range from the northern frontier of Sind to the termination of the range within the province about fifty miles south-by-west of Sehwán. It also composes the range which under various names, Lakki, Eri, Daphro, &c., runs south from Sehwán to beyond Bula Khán's Thana, and the several ridges to the westward near the Habb, the southernmost of which terminates at Cape Monze. It, moreover, occupies a considerable [illegible] of country near Kotri and Jhirk (Jerruck), and forms the isolated hills of Sakhar (Sukkur), Rohri, Hyderabad, and Tatta.

4. NARI OR UPPER NUMMULITIC GROUP.

The upper sub-division of the nummulitics of Sind is, where best developed, very nearly, if not quite, equal in thickness to the lower, but its composition is very different. At the base it contains a variable thickness of brown and yellow limestone abounding in *Nummulites garansensis, N. sublævigata*, and *Orbitoides Fortisi* (= *O. papyracea*, Boubée), interstratified with sandstone and shale. These beds are in places five hundred feet thick, but usually

much less. All the upper portion of the group consists of massive sandstone beds, which are generally quite unfossiliferous, but occasionally contain bands of clay and shale with fragmentary plant remains. Towards the base of the sandstone, beds of limestone with the characteristic *Nummulites* are occasionally interstratified, sometimes five hundred feet, or even more, above the principal limestone beds at the base of the group; thus clearly showing that the limestones with *Nummulites garansensis*, &c., belong to the same sub-division of the tertiary series as the sandstones.

In many places, especially towards the base, very ferruginous bands are interstratified with the sandstones; and south of Sehwán, on the west side of the Bhagotoro range, where the thickness of the whole group is much less than in the Khirthar range, the upper portion consists of ironstone, ferruginous sandstones, and brightly coloured clays, purple, brown, and white. On the Khirthar range, however, almost the whole group, except at the base, is composed of massive beds of brown sandstone. Throughout the area examined, the upper nummulitics rest conformably upon the lower, but there is a complete break in mineral character, and the fossils are different, the two characteristic species of Nummulite, for instance, being distinct from any hitherto found in the Khirthar group.

The whole thickness of the Nari group on the Khirthar range can scarcely be less than five thousand feet.

In some places the limestones at the base of the Nari group contain a large number of Mollusca and Echinodermata. The following have been identified; a large proportion are from Bhagotoro, south of Sehwán:—

Foraminifera.

Nummulites garansensis.
N. sublævigata.
Orbitoides Fortisi.*

Echinodermata.

Cidaris Verneuili.
Cœlopleurus Forbesi.
Echinanthus profundus ?
Echinolampas, sp. nov.
Eupatagus rostratus.
Schizaster Beloutchistanensis.
S. Newboldi ?

Lamellibranchiata.

Corbula harpa.
Venus granosa.
Cardium triforme.
Pecten Labadyei.
Ostrea flabellula.

Gasteropoda.

Natica patula.
N. sigaretina.
N. decipiens.
Siliquaria Granti.
Solarium affine, 2 vars.
Trochus cumulans.
Phasianella Oweni.
Turritella Deshayesi.
T. angulata, var.
T. Renevieri.
Triton Davidsoni.
Voluta jugosa.
V. dentata.
Cypræa nasuta and other species.
Terebellum obtusum.
The most common forms being the *Foraminifera* and *Pecten Labadyei*.

* O. papyracea (Boubée); see Geological Magazine, November 1875, p. 535. As before remarked, for convenience sake, D'Archiac and Haime's specific names are preserved throughout this paper. I believe this rhizopod to be correctly identified, but at the same time it appears to me to be the species identified by Dr. Carter with O. Mantelli.—Journal, Bombay Branch Royal Asiatic Society, vi, pp. 79, 82, &c., &c.

Although the relations of the fossils named above appear, on the whole, to be Eocene rather than Miocene, there being a predominance of species such as *Natica patula*, *N. sigaretina*, *Ostrea flabellula*, *Voluta jugosa*, &c., found, or represented by closely allied forms, in Eocene beds in Europe, there is a considerable admixture of species with Miocene affinities, such as *Siliquaria Granti*, *Solarium affine*, and *Echinanthus* (*Clypeaster*). Of the two characteristic species of Nummulites also, one, *N. sublævigata*, is peculiar, being unknown out of India, whilst the other, *N. garansensis*, is met with in the lower Miocene beds of France.*

It should not be forgotten that the fossiliferous beds are at the base of the Nari group, and if, as appears probable, these are high Eocene, the upper portion of the division may, very possibly, be of Miocene age.

The rocks of the Nari group extend nearly throughout the Khirthar range, forming a belt of lower hills along the western base of the main ridge. This belt varies greatly in breadth, but is rarely less than from two to three miles across, except in the extreme north, close to the frontier, where these beds are cut out apparently by a fault, or squeezed into a narrow belt, a few feet in width, and in the extreme south, where they appear, in places, to have been removed by denudation. On the Gáj river, the tract of country occupied by upper Nummulitic rocks is about three and a half miles wide; on the Nari Nai, from which its name is taken, it expands greatly and is six miles broad. The same rocks occupy the broad valley of the Angai stream south of the Nari, and, sweeping round the northern termination of the Bhit range, form the greater portion of the valley to the eastward Their area in this direction has, however, yet to be ascertained. They are largely developed in the broad valley of Chorlo and Malirri running south from the Manchhar Lake, and they are met with again about Tatta, but they do not appear to be found east of the Laki Kara and Eri range between Sehwán and Kotri. They, however, occupy a large tract of country near Júngsháhi, and are represented in many parts of Kohístán. Their area towards Karachi remains to be determined.

5. Gáj or Supra-nummulitic Group.

Above the sandstones of the Upper Nummulitics there is found a group of highly fossiliferous limestones, sandstones, and shales, distinguished by a very different fauna, from which *Nummulites* are entirely absent. This group is easily recognised by being composed of several thin bands of hard limestone, usually of a brown colour, but occasionally white, with sandstones and shales interstratified, in bands of small thickness. The limestone weathers into ridges which may frequently be traced for miles amongst the outer hills of the Khirthar range.

The most characteristic bands of limestone are about the middle of the formation. They contain *Echinodermata* (especially *Breynia carinata*) in considerable quantities, and they frequently abound in corals. The *Echinodermata* appear, as a rule, to be confined to one bed, but further examination is necessary: all that can be positively asserted is, that a band of limestone, abounding in fossil sea-urchins, occurs throughout a large area at about the same horizon. Towards the base of the group shales and sandstones prevail, but the latter may, as a rule, be easily distinguished from similar rocks in the underlying Nari group by being comparatively thin, each bed rarely exceeding eight or ten feet in thickness, and by their being interstratified with shales or limestone, often fossiliferous. The upper portion of the Gáj group consists usually of calcareous sandstone and hard marls, with shales and clay, and the uppermost beds frequently abound in *Turritella angulata* and other allied species of the same genus. In some localities, as on the [illegible] Nai, and again

* D'Arch. and Haime, An. Foss. Num. de l'Inde, p. [illegible]

on the Khenji Nai, the highest beds of the group are clays with gypsum, containing, besides *Turritella angulata*, the following fossils:—

Corbula trigonalis.	Tellina subdonacialis.
Lucina (Diplodonta) incerta.	Arca Larkanensis.

These beds may, very probably, be estuarine, for *Arca granosa*, the living Indian representative of *Arca Larkanensis*, is one of the most typical of estuarine mollusks, and the *Tellina*, *Corbula*, and *Diplodonta** all have allies living in estuaries. These supposed estuarine beds are quite conformable to the overlying Manchhar (Sevalik) group and appear to pass into it.

The Gáj group, where best developed, as on the Gáj river, is at least one thousand feet thick. As a rule, throughout the Khirthar range, it is conformable to the Upper Nummulitics, but west of the Manchhar Lake, near Tandra Rahim Khán, it rests unconformably upon all the older beds, for its outcrop extends in a nearly straight line across the Angai valley, which is formed by a synclinal of the Nari or Upper Nummulitic group. Further south, in the country south-west of Bula Khán's Thana, the Gáj beds are nearly horizontal over a large area, whilst the nummulitic beds, both Khirthar and Nari, where they rise to the eastward from beneath the newer formation, exhibit much greater disturbance. In one spot near Bula Khán's Thana Gáj beds were found resting directly on Lower Nummulitics.

The following is a list of the principal fossils identified from the Gáj group. Foraminifera are not very common, and hitherto in Sind, as has been already mentioned, no species of *Nummulites* has been observed in these rocks:—

Foraminifera.

Operculina canalifera?

Echinodermata.

Cœlopleurus Forbesi, var.	Echinolampas Jacquemonti.
C. (sp. nov.?)	E. spheroidalis?
Echinus Stracheyi?	Breynia carinata.
Echinanthus profundus.	Brissus (Meoma) sp.
E. halaensis? var.	Maretia sp. (undistinguishable from the recent *M. planulata*).
E. sp.	Schizaster sp.
Echinodiscus sp. (near the recent *E. auritus*, but with closed lunules).	

Lamellibranchiata.

(? Kuphus) rectus† (Serpula recta, Sow).	Arca Larkhanaensis.
Corbula trigonalis.	A. Peethensis.
Tellina (Macoma) subdonacialis.	A. Kurrachiensis.
Lucina (Diplodonta) incerta.	Pectunculus pecten.
Astarte hyderabadensis.	Pecten corneus.
Venus granosa.	P. Bouei.
V. cancellata.	P. Favrei.
V. (Tapes) subvirgata.	Spondylus Tallavignesi.
V. (Dosinia) pseudoargus (= *D. exasperata*, Chemnitz, recent).	Ostrea multicostata.
	O. hyotis (recent).
Cardium anomale.	O. denticulata (ditto).

* Mr. G. Novill has done me the favour of comparing the *Diplodonta* and some other species, and I learn from him that a living species common in the Indian seas, which neither of us can distinguish from the fossil *Diplodonta*, is unnamed. I am not acquainted with the precise habitat of the living form, but either the same or a closely allied species occurs with estuarine Mollusca at Bombay. The *Tellina* belongs to the subgenus *Macoma*, and is very close to *T.* (*Macoma*) *myaformis*, Sow., a common recent estuarine species.

† A form undistinguishable from this is found also in the Khirthar group. In both cases the tube is certainly that of a mollusk, not of an annelid.

Gasteropoda.

Turritella angulata.
Buccinum Vicaryi.
Buccinum Cautleyi.

Crustacea.

Balanus sublævis.
Palæocarpilius rugifer.*

The most characteristic fossils of the formation are *Breynia carinata* and *Ostrea multicostata*. Species of *Clypeaster* (*Echinanthus* apud D'Archiac and Haime), *Echinolampas Jacquemonti*, *Kuphus* (?) *rectus*, *Venus granosa*, *Arca Larkhanaensis*, *A. Peethensis*, *A. Kurrachiensis*, *Pecten Favrei*, *Turritella angulata*, and *Balanus sublævis* are also common.

That the above fauna is later than Eocene is self evident, the genera of Echinodermata alone being amply sufficient to prove the later tertiary age of the rocks. I feel some doubt as to whether the group is as old as the Miocene of Europe. It must be borne in mind that one important characteristic of the European Miocene is the presence of genera now confined to tropical or subtropical seas, and consequently a similar fauna in subtropical Indian rocks may indicate a later geological age. The definite test of the age of Indian later tertiary rocks must be the same as that applied by Lyell and others in Europe—the comparison of the fossils with the fauna now living in neighbouring seas—and until this can be made, only a provisional age should, I think, be assigned to the beds. Whilst, therefore, the Gáj group may for the present be called Miocene, as forming the middle tertiary group of Sind, I think it possible that it may ultimately prove Pliocene, and that the Nari beds are, in part at least, the equivalents of the European Miocene. Bearing in mind that the fossiliferous beds at the base of the Nari group have unmistakable miocene affinities, it is impossible to consider the Gáj beds older than Upper Miocene.

The Gáj group is found throughout the Khirthar range, and usually forms the first well marked ridge west of the lower hills of soft Sevalik (or Manchhar) sandstones. South of the Nari Nai, this belt of middle tertiary beds turns to the south-east, and finally more to the eastward, and it forms a range of hills of small elevation about four miles south-west of the Manchhar Lake. To the south-west of the lake, the group appears to be entirely wanting, and the Sevaliks rest, apparently conformably, upon the Upper Nummulitics (Nari). The Gáj beds are also absent east of the range running south from Sehwán.† They, however, appear in places in the valleys to the west of that range, near Bula Khán's Thana; and south-west of that place and of Tong they occupy a very large tract of country, hitherto imperfectly examined, extending south-east towards Júngshâhi, and west towards the Habb river, along which they stretch to the neighbourhood of Karachi. Their relations with the overlying rocks in this country require further examination.

6. Manchhar or Sevalik Group.

The highest group of the Sind tertiary series has hitherto received but little attention. It is unfossiliferous as a general rule, and there can be but little doubt of its representing formations better exhibited and more fossiliferous in the Sub-Himalayan region, and already widely explored. It is far from impossible that further study of the Sind beds may show that they are separable into two or more sub-groups. In one instance at least there was observed evidence of probable unconformity between different portions of them.

* Stoliczka, Pal. Indica.

† A bed only two or three feet thick has just been found representing them near Vero. It rests on Khirthar limestone, and contains *Ostrea multicostata*, *Pecten Favrei*, &c.

The Sevalik beds in Sind consist of clays, sandstones, and conglomerates. The clays are usually buff or red in colour, the sandstones reddish-brown or grey. One very characteristic bed is a rather fine greenish-grey sandstone composed of fragments of quartz, felspar, and hornblend. This sandstone is often quarried for platters used to bake bread upon. In the reddish-brown sandstone the hornblend is absent.

The conglomerates vary much in character. As a general rule, and especially towards the base of the group, they contain rolled fragments of argillaceous sandstone and clay, closely resembling the associated beds in the same group. As a rule, too, except in the upper conglomerate at the top of the group, pebbles of the older tertiary formations are wanting; but in a few instances they have been found. This is the case in one bed on the Khenji Nai, and conglomeratic bands containing Nummulitic limestone and Gáj (Miocene) limestones are seen on the road between Shah Hassan on the Manchhar Lake and Pir Gáji.

On the top of the Manchhar or Sevalik and on the edge of the alluvium there is found, in most parts of the Khirthar range, a very thick bed of coarse conglomerate composed of large pebbles of nummulitic limestone and other rocks, amongst which fragments of a quartzite are abundant. This conglomerate bed in places, as at the outlet of the Gáj, cannot be less than two or three hundred feet thick. It is disturbed and inclined like the Manchhar beds beneath it, and it appears conformable to them. It has, however, an appearance of passing upwards into the gravels of the slope outside the range, but such appearances are sometimes fallacious. At the same time it is far from improbable that the conformity of this conglomerate to the Manchhar beds may be only apparent.

The thickness of the Manchhar group in Sind has not been ascertained with any certainty, but it can scarcely be less in places than five thousand feet.

Except near Karachi, where some oysters were found by Mr. Fedden in beds apparently belonging to this group,* no marine fossils have hitherto been obtained in it, and the principal recognizable remains of vertebrata hitherto collected by the Survey are some bones and teeth of Rhinoceros and Crocodile. Captain Vicary and some other explorers appear, however, to have found bones in larger numbers.

From the circumstance that the Manchhar group rests unconformably on the Gáj beds, which are at the oldest Upper Miocene, it is manifest that the Manchhar group itself cannot be older than Pliocene. This result is extremely important, if, as appears almost certain, the Manchhar beds of Sind are the equivalents, in part or wholly, of the Sevalik and Nahun beds of the Punjab, since the latter have generally been referred by all writers to a Miocene epoch.† The Makrán group, the possible equivalent of the Manchhar in Baluchistán, is newer Pliocene or Pleistocene.

It appears to me that the Sind beds cannot be of marine origin. With one or two local exceptions, they are entirely destitute of mollusca or other forms of marine animal life, whilst similar beds in the Gáj group just below are full of fossils. The coarse conglomerate at the top of the group is chiefly composed of pebbles which appear to have been rolled in streams, their form being too oblate for them to have been formed on a sea beach. I am strongly disposed to suspect that the Manchhar group, despite its enormous thickness, is

* Within the last few days, some more oysters have been found, also by Mr. Fedden, at Vero, west of Kotri. They are accompanied by two kinds of *Balanus*.

† I have, for a long time past, doubted whether the Sevalik rocks were correctly referred to so early a date as [illegible], and I expressed my doubts, mainly founded on the great proportion of remains of ruminants to those of other orders, to Dr. Falconer himself as long ago as 1862.

of subaerial origin, the clays having, probably, been formed in an alluvial plain, and the conglomerates and sandstones deposited by streams and the wash of rain from hills.

The Manchhar group is unconformable to the Gáj group. This is proved by the occurrence of fragments of the Gáj limestones in places in the Manchhar conglomerates, and also by the newer group in places near Sehwán and Kotri overlapping the older and resting unconformably upon the upper or lower Nummulitic beds. But, as a rule, throughout the Khirthar range, the Manchhar beds rest conformably on those of the Gáj group.

The Sind Sevaliks form a belt of low hills on the flanks of the Khirthar range as much as fourteen miles in breadth near Ghaibi Dero, west of Larkana, but usually not more than four or five miles wide. South and west of the Manchhar Lake the same rocks occupy a considerable tract of undulating country. They are found on the west side of the Laki hills, south-west of the Manchhar, and they cover much of the ground between the Indus and the continuation of the same range to the southward. They are also met with locally about Bula Khán's Thana and in some of the other valleys of Kohístán. Their extent near the coast is obscure, for they appear to change in character in this direction, and they may be represented by the Makrán group:* but this point has not been determined as yet.

The Manchhar beds were evidently deposited before the elevation of the Khirthar range, since they are tilted up with the beds of which the higher hills are formed. They thus mark the close of the tertiary period in Sind, and a break exists between them and the undisturbed formations of more recent date.

7. Recent and Sub-Recent Deposits.

Although these cover the greater portion of Sind, they possess but little geological importance by themselves. They are merely local forms of wide spread formations, and, from their simplicity, demand but brief notice.

The alluvium of the Indus plain is rather sandy, perhaps in consequence of the great extent to which sand is carried over the country by wind. Otherwise the alluvium presents no peculiarities, or at least none have been observed.

Along the base of the Khirthar and other ranges are slopes of gravels similar to those found in Persia and the dry regions of Central Asia, but on a much smaller scale. These deposits are evidently due to the wash of rain and small streams, and similar slopes occur in all countries, but they are peculiarly conspicuous in the desert regions, in consequence of the absence of vegetation.

Large accumulations of gravel and sand are found in many of the valleys between the ranges in Lower Sind and amongst the lower hills of the Khirthar. These gravels are often cemented into a conglomerate by carbonate of lime.

Blown sand is frequently found in parts of the Indus plain covering the surface and forming low hillocks. To the east of the Indus it covers a large tract of desert country, separating Sind from Rajputana.

On the correlation of the Sind tertiaries with those in neighbouring countries.—The importance of a knowledge of the rocks of Sind, for the purpose of affording a clue to the tertiary geology of other parts of India, has already been noticed. Much additional study of the fossils is necessary before anything like accurate correlation is practicable, and it is possible that the distribution of organic remains in the tertiary rocks of other parts of India may differ slightly from that found in Sind.

* Records, Geological Survey, India, 187[illegible], vol. [illegible], p. [illegible].

The tertiaries of Kachh, south-west of Sind, were described by Captain Grant in 1837, and have since been mapped and classified by Messrs. Wynne and Fedden (Mem. Geol. Surv. India, Vol. IX). The following groups were distinguished by the latter. I place against each its probable equivalent in Sind:—

Kachh.	*Sind.*
F. Upper Tertiary.	Manchhar or Sevalik.
E. Argillaceous group.	Gáj or Supra-Nummulitic.
D. Arenaceous group.	Nari or Upper Nummulitic.
C. Nummulitic group.	Khirthar or Lower Nummulitic.
B. Gypseous shales. A. Sub-Nummulitic.	? Ranikot or Infra-Nummulitic.

At the same time it is only just to state that these identifications are chiefly based upon fossil evidence contained in the detailed descriptions,* and that this evidence does not always coincide with the distribution of organic remains found in Sind. For instance, Nummulites are said to have been found in the argillaceous group of Kachh,† whilst none have hitherto been met with in the corresponding Sind formation. Mr. Fedden tells me that it is probable that the mapping of portions of the Kachh tertiaries, which are frequently very ill-exposed, may require alteration. Some of the identifications of fossils, too, were made with imperfect means of comparison. Unfortunately it is not specified in the Memoir which of the identifications are by Dr. Stoliczka, who compared most of the forms enumerated in the detailed descriptions.

Of Kathiawad we only know as yet that a tertiary series is found, near the base of which Nummulitic limestone occurs. Above this Mr. Theobald, in his manuscript report, enumerates in ascending order (α) *Venus granosa* beds, which are probably, in part at least, the representatives of the Gáj group of Sind; (β) Perim beds, approximately of Sevalik age, and, therefore, corresponding to the Manchhar group of Sind, and (γ) Milliolite beds, which are, possibly, the equivalents of part of the Mákrán group, and are not, so far as we know, represented by marine beds in Sind at all.

In Eastern Gujrat,‡ in the districts of Surat and Broach, the tertiary formations above the volcanic series of the Deccan traps are very ill-exposed. Near their base limestone is found with numerous fossils, several of which are characteristic of the Sind Khirthar group (Eocene), whilst higher in the series sandstones, clays, and gravels with *Balanus* and other fossils occur. These may, possibly, represent the Gáj group of Sind.

Turning northwards from Sind, the first place (with the exception of the hills north of the modern Jacobabad, briefly described by Captain Vicary) of which we have any definite information is the portion of the Suliman range, recently examined by Mr. Ball,§ west of Dera Ghazi Khan. Mr. Ball describes beds, which he considers of Sevalik age, resting upon sandstones with clays; the latter beds are, probably, the representatives of the Sind Manchhar group, and Mr. Ball's Sevaliks may correspond to the massive conglomerate found in Sind at the top of the tertiary series.

Of course, considering that Mr. Ball made only a flying visit to the hills at the most unfavourable season of the year, he may have easily overlooked some groups, and representatives of the Gáj and Nari beds of Sind could scarcely have been detected without a careful survey. Still the absence of the massive sandstones of the former group is important.

* l. c. pp. 231, 239.
† pp 258, 280.
‡ Memoirs Geological Survey of India, VI, pp. 61-65, 206, &c.
§ Records Geological Survey of India, VII, p. 145.

But the lower portion of Mr. Ball's section corresponds well with what is known of Sind. He found Nummulitic limestone, evidently of Khirthar age, resting upon a great group of alum shales and sandstone with coal, apparently representing the Ranikot beds of Sind.

So little has as yet been ascertained definitely about the Punjab tertiary rocks, that it is best to defer all attempts at identifying them until more is known of their organic remains. With the Sub-Himalayan rocks described by Mr. Medlicott,* the following are possible identifications, but the absence of marine fossils in the two upper sub-divisions of the Sirmúr group renders comparison difficult:—

Sub-Himalaya near Ganges.		*Sind.*
Sevalik	...	Manchhar.
Náhan	...	Manchhar.
Sirmúr ...	Kasaoli ...	?
	Dagshai ...	?
	Sabathú ...	Khirthar.

The most striking point is that, so far as the examination has hitherto proceeded, no marine representative of the Gáj Miocene group has been found north of Sind, unless the occurrence of a single valve of *Lucina (Diplodonta) incerta* in the Salt range† be evidence of its existence. Mr. Medlicott notes the existence of *Ostrea multicostata* in the Sabathú group,‡ but it is far from clear that this species, although it is so common in the Gáj group as to be a characteristic fossil, is confined to that horizon even in India. In Europe it is an Eocene form. Whether the Kasaoli or Dagshai beds represent the Nari group of Sind remains to be determined.

Lastly, west of Sind, in Mákrán, there is found a thick group of marine beds of very late age, certainly not older than Pliocene. This group, which is greatly developed near the coast, I have proposed to call the Mákrán group.§ It rests with apparent local conformity on an immense thickness of sandstones and shales, in which occasionally beds of Nummulitic limestone occur. All this lower portion of the series, in the only country in which I was able to examine it, is greatly disturbed and altered, all the beds, as a rule, being vertical or nearly so, and it was impossible to classify the rocks below the Mákrán group.

This Mákrán group is certainly unrepresented in Sind by any marine beds hitherto examined: (it must be borne in mind that the neighbourhood of the coast requires further attention:) most of the included fossils are recent species, and not a single characteristic Gáj (Miocene) form has been detected in Mákrán except *Arca (Parallelopipedum) tortuosa*, which may prove undistinguishable from *Arca Kurrachiensis*.

The natural suggestion arises that the Mákrán group may represent the Manchhar formation of Sind: but this remains to be proved. The one formation is exclusively marine, the other freshwater, and until the intervening area has been examined, it would be premature to speculate upon the relations of the two to each other.

P.S.—December 23rd, 1875.—Since the above sketch of Sind geology was written, the rocks beneath the Khirthar group have received further examination, and the result shows that the fossiliferous brown limestones of Tatta, Jhirk, and the country north-west of Kotri must be classed with the Ranikot or Infra-Nummulitic, and not with the Khirthar

* Memoirs, Geological Survey of India, III, pt. 2, pp. 17, &c.
† D'Arch. and Haime, An. Foss. Num. de l'Inde, p. 240.
‡ l. c. p. 100.
§ Records, Geological Survey of India, 1872, Vol. V, . 41.

group. A list of some of the principal fossils obtained from these brown limestones was given above (p. 12). It has also been ascertained that the Khirthar group rests unconformably, in places at least, on the Ranikot group, the unconformity being clearly seen at Hothian pass, ten miles south of Ranikot. This unconformity explains the absence of the fossiliferous brown limestones, which are the highest known members of the group, at Ranikot itself.

Basalt, precisely similar to that seen at the base of the Ranikot section, has been traced in several places along the range north of Ranikot, and proves to be a lava flow 30 to 40 feet in thickness, distinctly interstratified with the sedimentary beds of the Ranikot group. A second flow has been found at a lower horizon. The bed containing *Cardita Beaumonti* is inferior to the upper basaltic stratum.

Beneath the shales and sandstones exposed at Ranikot, and below the *Cardita Beaumonti* bed, there is a great thickness of brown, reddish, and white sandstones and conglomerates and some dark-coloured gritty limestone, and at the base of these beds white limestones appear, in which no nummulites have been detected and which may prove cretaceous. Unfortunately, the south of Sehwán and Lakki Range, in which the sections are exposed, is difficult of access. It is hoped that a fuller account of these interesting beds may be given hereafter.

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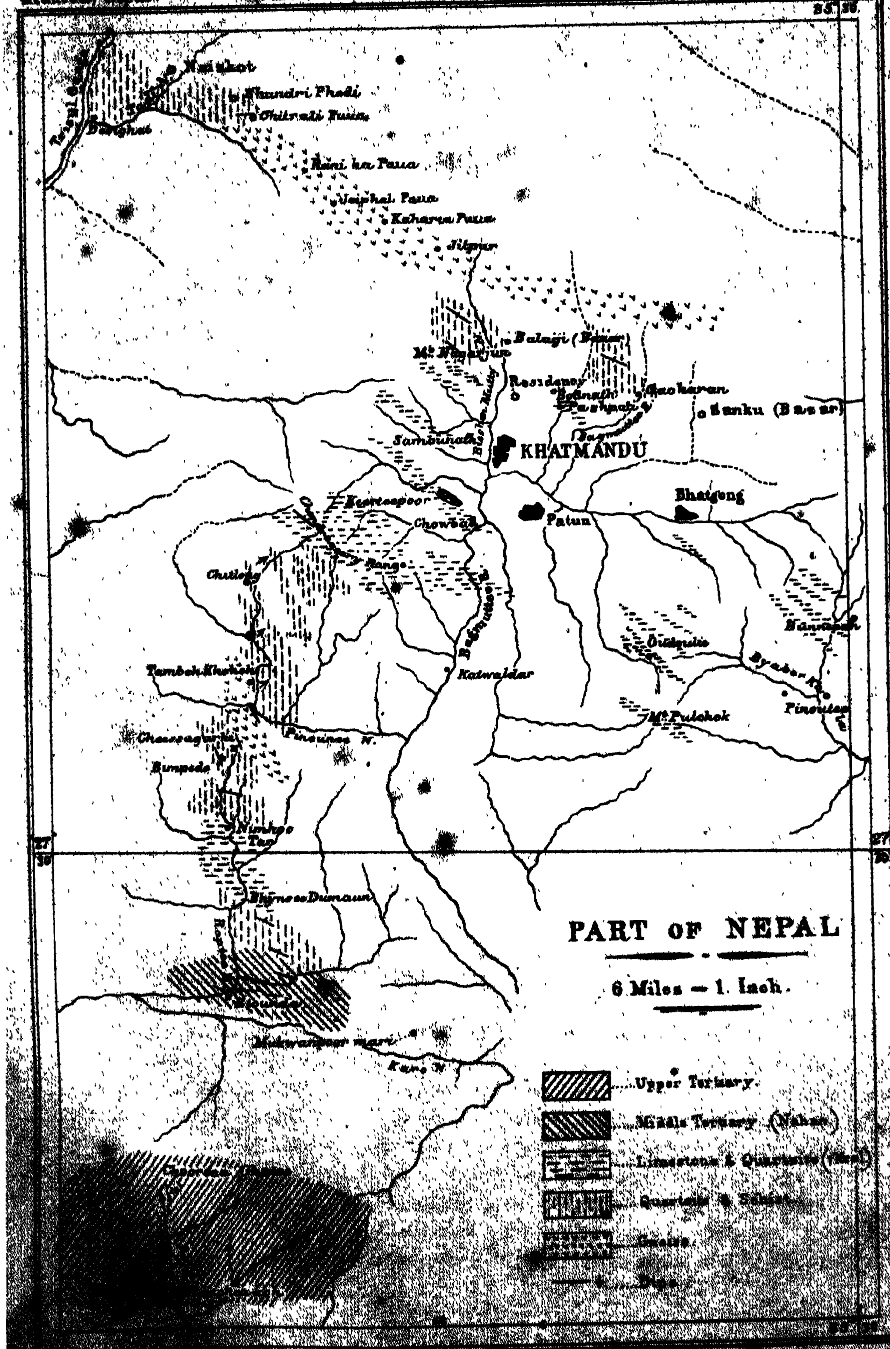

PART OF NEPAL
6 Miles = 1. Inch.
Upper Tertiary.
Middle Tertiary
Limestone & Quartzite
Quartzite & Schist
KHATMANDU
Patun
Bhatgong
Residency
Sanku (Bazar)
Balaji
Sambunath
Chowbar
Katwaldar
Chitlong
Bhimphedi
Mt Pulchok
Pinsuna N.
Karra N.
Jitpur
Rani ka Paua
Chitrali Paua
Shundri Phedi
Nimbo Tar
Tambah Khan
Chessapani
Bhynse Dumaun
Sankhu
Bagmati R.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1875. [November.

NOTE ON THE GEOLOGY OF NEPAL,* *by* H. B. MEDLICOTT, M. A., F. G. S., *Deputy Superintendent, Geological Survey of India.*

Through the kindness of Mr. Girdlestone, the Resident of Nepal, I had an opportunity in May last of visiting that very secluded country. It will surprise many to hear that although the marches of Nepal run for more than 500 miles along some of the most fertile and populous districts of British India, that country is still rigorously tabooed to all outsiders, Englishmen included. With the exception of the track to Katmandu, no part of that extensive area has been traversed by civilized man. Even the route to the capital is only open to political envoys, and by special favor to invited guests; and any digression from the actual road-way is suspiciously watched. The permitted range of exploration from Katmandu is correspondingly restricted: one may go as far as the Trisal-ganga, on the north-west, about sixteen miles (direct), and to about an equal distance on the south-east, in both cases a short way beyond the precincts of the actual valley. The following observations are therefore most scanty, there being no opportunity to follow up and examine features of special importance in the general section. They may, however, have some interest as a term of comparison between the known ground on the east and on the west, about midway between which this section occurs.

It is necessary briefly to state what the features are with which this comparison is to be made. From the Sutlej to the western frontier of Nepal there is continuously traceable along the margin of the mountains a zone of variable width formed of slates and thin silicious beds surmounted by sandstone and strong limestone. The latter have been described as the Krol group; the lower horizons being distinguished as infra-Krol, Blini (a thin limestone) and infra-Blini. They usually form a broad, crushed synclinal ridge at the edge of the mountain-area, as at Mussooree and Naini Tal. In the Simla region they extend far beyond this ridge into the interior of the mountains, where they become obscured by metamorphism, their relation to the gneiss rocks not being as yet satisfactorily determined. In Kumaon, at least north of Naini Tal, there is an abrupt change, along a line of trappean intrusion, between the range of semi-metamorphic strata and the gneiss rocks to the north. It has been conjectured that the Krol limestone is triassic, and the underlying groups palæozoic.

* Within the territories the name Nepal is only applied to the valley of Katmandu.

The section in Sikhim, to the east of the Nepal territories, is petrographically very different from that in the Simla region. The schists and gneiss come close to the edge of the mountains, in some places quite up to it. But in many parts there is a narrow band of partially altered strata, which have been fully identified as belonging to the Damuda formation, the coal-measures of India, thought to be of upper palæozoic age. But the curious point is that these beds are the lowest and oldest member of the rock-series, conformably underlying the schists, and these again passing regularly beneath the gneiss, which forms the greater part of the mountains in the Darjiling district. In Sikhim the usual outer ranges of the sub-Himalayan hills, enclosing long valleys at the base of the mountains, are not represented. The inner zone of sandstone at the very base of the mountains is, however, in force.

In the Nepal section we find a very complete exhibition of the sub-Himalayan hills, as known to the north-west. The Churia Ghati range, in size, structure and appearance is a *fac simile* of the original Sivaliks. Inside it the *dún* or *mari* of Etoundah is an excellent example of these characteristic sub-Himalayan valleys. And to the north of this, along the base of the mountains, there is a flanking range of sandstone, harder, and apparently older, than that of the outer hills, just as occurs in the western region. There is still so much uncertainty about the grouping and distribution of these sub-Himalayan rocks, that I cannot speak confidently as to those in the section under notice. It is quite recognised that there are two strong and stratigraphically well separated groups—the Sivalik and the Nahan—in the trans-Jumna region; but considerable doubt has been thrown upon the view I at first adopted, that the cis-Jumna Sivalik hills belong to the upper group of rocks. Lithologically, the resemblance is more with the Nahun than with the Sivalik group. Thus it would appear that structural position, even in the case of what is physically a single range, is no criterion of the geological horizon of the rocks; and we are unable on these grounds to assume that the Churia Ghati strata are true Sivaliks. Lithologically too, they have small resemblance to the typical Sivaliks of the trans-Jumna range. In mere composition they are much more like rocks of the cis-Jumna hills, consisting as they do in the lower half, of massive gray sandstone, and above of great beds of conglomeritic gravel. There are, however, some points of difference: in the west the change from the sandstones to the conglomerates is gradual and alternating; here it is rapid and complete, from an almost unbroken mass of fine grey sand to an equally uniform mass of pale yellowish-brown conglomerate. This character can have no significance; but I was much struck with the very fresh aspect of these Churia Ghati deposits as compared with those of the range south of the Dehra-Dún. The sand, in solidity as well as in appearance, is scarcely different from that forming the *chars* (temporary islands) in the great river beds. I should, perhaps, mention that it is several years since I have seen the Sivalik sections, and have since then been occupied with much more ancient formations. On one point, however, I will speak firmly: I must at present refuse to believe that the Churia Ghati strata can be of the same horizon as the sandstone forming the hills north of Etoundah; and so, these being presumably Nahans, the former may for the present be set down as Sivalik.

At the outer base of the range, at Bichiakoh, there are some rusty earthy beds; and all are greatly crushed, locally quite vertical. The dip soon settles down to 30°, to north-north-west, maintaining it steadily to the top of the pass. This is the type structure of these detached sub-Himalayan ranges, of whatever group composed: the flat half of a normal anticlinal flexure. The range is about four miles wide, which would give an aggregate thickness of about 10,000 feet of rock.* The pass, as is universal in these ranges,

* It is still necessary to note that this does not imply vertical sequence.

follows the broad bed of a torrent, to near the very summit, where it turns up a steep gully, partly artificial. Here I noticed a strong bed of ochreous clay. A similar rock is very common in a like position in the passes south of the Dehra-Dún. Boulders of from 12 to 20 inches cube are common in the bed of the torrent, though it is rare to see stones of this size in the conglomerate forming the cliffs on each side, from which, it would be assumed, all must be derived. Near the foot of the steep rise I observed a huge block of quartzite, measuring 10′ × 7′ × 6′. Reference to it will be made further on.

In the Rapti, immediately under Etoundah, there are outcrops of the rusty sandy clays and greenish-gray sandstone at the base of the section north of the dún. They dip at 60° to north-by-east. Wherever observed along the road, this dip (with slight variation in amount) was found constant, and there is but little change in the character of the rock. It is clearly an ascending section: clays occur, but very subordinately; the sandstone becomes somewhat softer in the higher beds, and there are here several layers of thin conglomerate. In no single feature is there any precise resemblance to the series in the outer range. The strata closely correspond with the Nahan group of the north-west, and with that described by Mr. Mallet at the base of the Sikhim Himalaya. At Etoundah the formation is about a mile wide, which would give an accumulated thickness of about 10,000 feet, there being nothing to suggest repetition by faulting or flexure. A blank covered space of fully 100 yards, between the last outcrop of the sandstone seen on the road section and the first outcrop of the slates, conceals the contact. It is probably, as usual, very steep, if not overhanging. Mr. Mallet has adopted for the Sikhim ground the view I put forward regarding this main feature of the mountain-structure in the north-west, that it is not primarily a faulted rock-junction. There is no sign at the base of the section, nor as a remnant along the junction, of any older tertiary rocks that might represent the eocene group of Subathu. The inner limit of these sandstone hills is well marked by narrow longitudinal valleys of denudation.

The first rocks seen north of the tertiary sandstone are some earthy schists, with a crushed dip of 50° to north-by-east, quite parallel in strike to the sandstone. A thin band of blue limestone occurs in these beds, and further on a strong band of black schistose slate, in which are some irregular vein-like nests of impure carbonaceous matter. All these beds within a few hundred feet of the boundary, though decidedly subfoliated, are less altered than any rocks to the north of them, and also less highly inclined. They are overlaid by more silicious rocks, flaggy schistose quartzite, nearly vertical, or folded in zigzag contortions. There is again a small appearance of more earthy schist, or possibly a reappearance of the former band, for the beds are greatly contorted, although the northerly underlie seems constant. A trappoid rock occurs here; but its intrusive character is not well marked. It is the only rock of this kind that I observed in Nepal. The thin quartzites come in again and pass up into stronger beds of the same rock, which are overlaid by massive white crystalline limestone, all dipping at 70° to 80° to north-by-east. This limestone must be several hundred feet thick. The sample I brought with me is not dolomitic. At Bhainsi Daman, where the river takes a bend, and above it for some miles, the rocks are much broken and confused. Great masses of the white limestone form irregular cliffs on both sides, the underlying rocks being concealed by vegetation and valley-deposits.

It would seem as if the ascending section from the boundary to Bhainsi Daman here passed into a broad, broken and contorted synclinal basin. The east-by-south general strike is maintained throughout; it was observed in some quartzites a mile below Bumphedi, which stands at the head of the valley close under the steep ridge of Cheesa-garhi. This glen of Nimbua-Tanr on the upper course of the Rapti is one of the most picturesque I have ever seen.

Although this Chessa-garhi range has a nearly east-west direction, parallel to the strike of the rocks to the south of it, it is formed, at least at this point, of rocks having a widely different direction. Even at Bimphedi, at the south base of the ridge, the strata strike to north 35° west. They are again thin quartzites, greatly folded and shattered, but maintaining a dominant high underlie to north-east-by-east. A little below the crest of the ridge on the northern descent, the quartzose schists are associated with strong bands of prophyritic gneiss, which is the dominant rock towards the base. The strike would take it into the ridge well within the basin of the Rapti. At the north base of the range the Pinouni river flows from the north against this mass of gneiss, and turns away to the east. Just above the bend of the river there is a cliff-section showing the crushed condition of the gneissic strata, contrasting well with the steady high underlie of the sharply bedded quartzites through which the river cuts its way obliquely. The general strike in both rocks is the same; and the whole feature suggests that the gneiss has been formed, and perhaps faulted up, along a broken anticlinal axis of flexure. It is near this line of disturbance that the copper mines of this locality occur. I was, of course, unable to visit and inspect them; but by a curious coincidence I passed at this very place a number of coolies laden with foreign copper for Katmandu, which suggests that the native resources in this metal cannot be very great. Here, and at several other places where I saw abundant refuse of old copper smeltings, the work seems to be now abandoned.

From the Sango bridge at Tamba Khoneh, along the Pinouni nearly due north to Marku, and then up the Chitlong valley to the north-east, there is an ascending section (obliquely) through the sharply bedded quartzites underlying steeply to east-35°-north. Wherever their composition is more earthy, foliation is well marked; but I did not see any gneissic band. Towards the head of the Chitlong valley the strike of the rocks becomes more easterly, up to the Chendragiri ridge, where it is east-15°-south; and the rocks are freely calcareous.

The Chendragiri ridge overlooks the Nepal valley, which is enclosed, except on the north, by rocks of the same description as those found here. There is, however, nothing like a circular arrangement of the ridges or of the rocks; the strike of both is most constant, between 15° and 25° to south-of-east; and the form of the valley is consequently most irregular—a number of longitudinal valleys, united in a central area by the suppression of the ridges, which are in some cases mere spurs running a short distance into the open; others, again, as that of Kirthipur, are nearly continuous across the valley: sometimes, as at Pashpati, the rock appears isolated in the alluvial deposits. The south-west corner of the valley divides the Chendragiri from the Phulchok range, on the same strike. Here at Kátwaldár, the Baghmati leaves the valley through rocky gorge across vertical quartzites. It is a moderately sized torrent, the watershed being confined to the ridges immediately surrounding the valley, which is only about sixteen miles long from west-north-west to east-south-east, and about twelve miles transversely, from Katawldár to the base of the Sheopuri range on the north. The alluvial area may be about 125 square miles. The elevation of Kátmandu is given as 4,500 feet. Phulchok on the south-east is the highest summit of the surrounding hills, rising to 9,720 feet.

Excluding the Sheopuri range on the north, all the ridges skirting or abutting into the Nepal valley are formed of steeply folded repetitions of one set of rocks, in which, as already noticed, a calcareous ingredient is very general. It often appears as limestone, in some force and of various degrees of purity. The summit of Phulchok is of thick white crystalline limestone. Strong beds are also found on Chendragiri and Nagarjan, both of which are syn[illegible]. The pure rock would thus seem to occur chiefly near the [illegible] of the series, but

some single beds are found low down. The schistose limestone of which the monoliths of Katmandu and Patun are made is quarried low down on the Kirthipur ridge at Choubal, where it is well seen at the gorge of the Baghmati. There are some thin bands of limestone also in the gorge at Pashpati. The prevailing rock is a peculiar massive, very fine schistose quartzite with a trifling percentage of carbonate of lime, yet to this minimum ingredient is, I believe, largely due the physical condition of this mountain zone—its deep erosion, as chiefly exhibited in the basin of the Nepal valley. This rock is very prone to decompose, by the abstraction of the small calcareous element in it, and is therefore seldom found in clear outcrops. It is well exposed in the little stream at the north-west side of Sambunath. For the most part it forms at the surface an ochrey sandy clay. When only partially decomposed it forms what might be called a sandstone (freestone). In this state it is quarried at the base of Nagarjan for building.

From the frequent reappearance of similar rocks across a broad zone of more or less vertical strata, one might of course presume that there is repetition by folding; but this condition is independently established: both Chendragiri and Nagarjan ridges, and those flanking Phulchok, are on synclinals. There would thus seem to be from the Pinouni into Nepal a repetition of the structural feature observed in the outer zone along the Rapti valley—an ascending section, only affected by minor foldings, through thinly bedded quartzose schists into a broad many-folded synclinal, in which an upper group of calcareous strata is frequently repeated at the surface. There is also sufficient likeness in the two series to suggest that they belong to the same formations, the most marked difference being the concentration of the calcareous element at the top of the southern section and its dispersion in the upper part of the northern one.

I would further venture to suggest that this series may be the continuation of the Krol and underlying formations of the Simla region. The flaggy quartzites of the lower horizons in the Nepal sections would very fairly represent the thin silicious beds that form so large a part of the Simla slates, or infra-Blini zone. Cases have, moreover, been recorded of the Krol limestone being represented elsewhere by more or less calcareous sandstone: a relation quite analogous to that now suggested between the strong quartzite and limestone of Bhainsi Daman and the calcareous quartzites of Nepal. Katmandu is in about the same zone of the mountains as Simla and Almora, being only thirty miles in a direct line from the plains. There are two points of contrast between the section here and in the Simla region, supposing the rocks representative: the contortion and the metamorphism of the strata in the latter position are local and partial, whereas in Nepal they are general and more or less complete. The limestone on the crest of the Chendragiri pass between Chitlong and Nepal is somewhat less altered than usual; in it I noticed some small facets of spar having a central puncture, and which I took to be crinoidal; but Dr. Waagen could not say positively that they were so.

On the north-north-east side of the valley the alluvial deposits rest against gneiss at the base of the Sheopuri range. The white patches so conspicuous along this edge of the valley are slip-faces in this rock where it is deeply decomposed. It is a coarse felspathic gneiss with much silvery mica and schorl. Its débris is a prominent ingredient of the valley deposits at Katmandu. On the spur north of Bodhnath and that connecting Sheopuri with Nagarjan, one finds very fine mica schists, first alternating with, and then succeeding to, the gneiss. The compression of the whole is so excessive and the underlie so variable, that it would be impossible to conjecture, without very detailed study, what the normal order of the strata may be. On nearing Nagarjan the underlie sets towards it; but the flaggy quartzites of Chitlong, which certainly underlie the calcareous zone, are not specifically recognisable in the

short section between the limestone and the gneiss. In crossing the range northwards, schists are frequently observed with the gneiss, always intensely crushed; but the general strike of the Nepal rocks is maintained. At Chitrali Powah, some height above the north base of the range, the gneiss is permanently replaced by schists, which here have a decided southerly underlie towards the gneiss. The valley of the Tadi and that of the Trisal-ganga between Debighat and the Nyakot sango are in these rocks, variously inclined at high angles, but with an east-north-easterly strike.

There seems to be scarcely any specific resemblance between the Nepal section and that in Sikhim, beyond the undoubted equivalence of the tertiary sandstones at the foot of the range. The slightly carbonaceous band at the base of the section in the Rapti valley cannot be directly identified with the coal-measure zone to the east, the associated rocks being quite unlike the Damuda sandstone, in which the crushed coal occurs at the base of the Darjiling section. Bearing in mind the great distance (more than 200 miles) between the two, it is, of course, quite possible that true equivalence may exist, but from simple petrographical comparisons, the carbonaceous schists of the Rapti would be more like the similar rock in Mr. Mallet's Daling series, over the coal band. The chief discrepancy occurs, however, in the ascending sections: in one case we find massive limestone, in the other massive gneiss. It would be idle to speculate upon the possible reconcilement of those features from such very scanty evidence. One may only notice that although the degree of metamorphism has increased from Nepal to Sikhim (if, indeed, the prevalence of gneiss does require this assumption), the degree of disturbance is far less marked in the latter area, judging from published descriptions.

It is truly vexatious to think that the settlement of questions of such wide scientific interest should be held in abeyance to gratify antiquated and barbarous official prejudices or customs. I met with the greatest civility from the few country-people with whom I chanced to come in contact. The obstructiveness is entirely on the part of those in power, who think their own dignity enhanced by exclusiveness. The officials at Katmandu were most anxious to obtain from me some useful information regarding a sulphur mine recently discovered at the base of Gosain Than mountain, in the upper valley of the Trisal-ganga, or rather in the main branch of that river that does not flow from the sacred lake; but nothing could persuade them to allow me to visit the locality. Their state of enlightenment in such matters may be judged from the fact that they imported from England a number of Davy lamps to counteract the effects of the noxious gases or vapours pervading the mine, but which I could not make out from their description to be of the nature of fire-damp. For much formal courtesy received I would offer my thanks to Sir Jung Bahadoor.

To the foregoing sketch of the older rock formations I would add a few words regarding more recent deposits. I have said that the Nepal valley contains some 125 square miles of alluvial land, but in precise language I am not prepared to say to what extent those deposits are alluvial or lacustrine. They are, on the whole, analogous to the Karewah deposits of Kashmir, as partially described by Major Godwin-Austen; but there is here no present lake, however small, to suggest a formerly more extensive water basin. The sacred myths, of course, record that the valley was once a lake, and even account in the usual miraculous way for its mode of origin; so far as I could observe, however, the oldest temples were founded during the existing phase of the surface, which is one of arrested erosion of a once continuous deposit. The feature all over the valley is flat uplands separated by broad flat valleys, locally called *Tánr* and *Khola*, and corresponding exactly to the *Bhángar* and *Khádir* of the upper gangetic plains. There is much artificial terracing where the upland flats pass into the rain-wash slopes from the mountains; but I observed only one regular river terrace,

that made by the actual course of the streams. Although, wherever a bend of the channel touches the edge of the upland, the side-erosion is still in progress, enlarging the area of the khola land, the rivers are not now lowering their bed. If any change is in progress, it is the reverse; the channels are very wide and shallow, and in some places at or above the level of adjoining cultivation. Such at least is the case above the gorge at Choubal; below it the channel is more confined, as occurs when a river is deepening its channel in this position the upper surface of the valley deposits must be 500 feet above the stream, which gives a minimum thickness for the formation.

There are within the valley three remarkable instances of the rivers having cut deep narrow clefts through rock-barriers. The one just referred to at Choubal is the largest, where the united drainage of the main area crosses the point of the Kirthipur ridge. There is another much higher up on the Baghmati at Gaokaran, through the point of a ridge flanking Sheopuri; and a third at Pashpati, where the Bishenmati passes through a low isolated outcrop of rocks on the strike of the Nagarjan ridge. They are mere clefts, narrower than are at all usual in the most confined gorges. One must suppose that the bygone conditions which produced them were in some manner special, and connected with the production of the alluvial basin; *i. e.*, they can hardly be accepted as remnants of the primitive channel of the Baghmati valley, before that simple feature of denudation had been converted in its upper area into a basin of deposition.

It may be presumed that the valley of Nepal is a true rock basin—that the rock-surface beneath some considerable portion of the covering deposits is below the level of the outcrop at the head of the gorge of outlet. It would seem indeed to comprise a series of such basins: if the clefts through the several ridges, as described in the last paragraph, were filled up, this would certainly be the case now; and that such has been the case there can be no doubt, for the beds now forming the adjoining terrace-land above those gorges could not have been formed had these outlets been then available. Thus the excavation of these rock-gorges by the existing rivers accounts for the present features of the valley deposits, and gives some measure of the antiquity of those features.

The fact of a rock-basin, even of considerable depth, does not involve a water-basin. This would depend upon the relative activity of the production of the barrier and of the accumulation of deposits above it, which cannot be independently determined. The question must be settled by observation as to whether the deposits are alluvial or lacustrine, and of this the evidence is not very fixed or easy of application. The degree of horizontality is one of the best tests, but needs much caution and accuracy in applying it; the slope at which true alluvial deposition may take place being so small, and there being always a chance of a very slight movement giving a tilt to originally horizontal layers. There is, indeed, sufficient evidence that some such disturbance has affected these deposits in Nepal: at several points, south of Bhatgaon and in the Kátwaldár area, along the south side of the valley, near the base of the hills, I observed dips as high as 15° in fine deposits, directed from the mountain. I could find no such occurrence in exactly similar deposits along the north edge of the basin. It would seem as if the action which originally formed the rock basin had been again, or still, at work after the formation of some of the highest beds. Major Godwin-Austen records a similar feature in the deposits of the Kashmir valley: a dip of 20° and upwards on the south and none on the north (Quarterly Journal, Geological Society, London, 1864, p. 383).

There is, however, one observation showing that at many different levels the surface at the time of formation was not a submerged one. Beds of an impure peat are of

frequent occurrence. I noticed them at the lowest levels exposed in the gullies close above the Kátwaldár gorge, and near the surface of the uplands north of Katmandu, and not confined to the edges of the valley. Thin layers of the same kind occur in Kashmir; but in Nepal they are thick, and pure enough to be much used for burning bricks. Such deposits are only compatible with swamping, such as is an ordinary concomitant of alluvial conditions. There is another deposit of extensive occurrence in Nepal, and of which I find no mention elsewhere. It is a fine stiff blue-gray clay, which is very extensively used all over the valley as a manure. Although it commonly contains particles of carbonized vegetable fibre, the little organic matter in it can hardly account for its fertilizing properties. This would seem to be due to the presence of phosphate: I noticed that blue specks of vivianite are freely scattered through the clay.

It will hardly be believed that I obtained no fossils from such deposits as these. I never was near a section without having a look out for shells, and I examined several spots carefully, without any success. This may be another argument for the alluvial mode of formation of the deposits, for certainly this process is not propitious to the preservation of organic remains. In extenuation of my failure I would mention that one of our best known Indian naturalists (Brian Hodgson) was for many years Resident of Nepal; he certainly would have at least noticed and recorded the fact had he observed any in the sections that confront one in every direction. The case is the more remarkable, since Major Godwin-Austen (in 1864) describes land and fresh-water shells as abundant in the Kashmir deposits. So at least it is in the south-east side of the valley; but in his first paper on the subject (in 1858), derived from observations on the north-west side, he remarks—"in all my wanderings amongst the Karewah Hills I never was able to find the slightest trace of a land or fresh-water shell in any of the many sections I have examined." I would urge the matter upon the attention of future dwellers in Nepal. The remains of mammalia or of plants would be specially interesting; and both might be expected to turn up occasionally in such beds as the peat and the phosphatic clay.

There is no temptation to attribute the rock-basins of the Nepal valley to glaciers. Even if it were proven that glaciers had extended to a much lower level, the form and conditions here are not such as would result from or account for the existing features through that agency. The valley is not in the course of any main drainage line; on the contrary, the watershed is closely restricted to the hills immediately surrounding, none of which are of great elevation. The valley is only a local exaggeration of what has occurred generally along this mountain zone. I have said that along the strike in both directions special denudation has taken place, which I have attempted to account for by the nature of the rocks; and in both directions we find the valleys more or less filled with deposits exactly like those of Nepal. The phenomenon is longitudinal with respect to the mountain system; and can be rationally understood as the effect of compression. The local yielding might be induced by the special excavation along this zone; and the effect would be a relative elevation of the ridges on the down side, producing rock-basins. It is an illustration of a process I appealed to last year in explanation of the cretaceous rock-basins in the Garo Hills (Rec. Geol. Surv. Ind., vol. VII, p. 62).

Although rejecting the intervention of glaciers in connection with the Nepal valley, I have been much puzzled with what I took to be glacial evidence elsewhere. Etoundah stands in the Dún exactly facing the gorge of the Rapti. The ground all about is strewn with great boulders, up to 10 feet cube, principally of coarse gneiss, high and dry above the present [illegible] the river, in which no such blocks are now to be seen. I came to the opinion that [illegible] be glacial erratics; although the elevation of the locality is probably well under

1,500 feet. . Proceeding up the valley I did not notice any such blocks up to Nimbuatanr, where the bottom of the valley is quite choked with an accumulation of similar blocks. These I took to be a later moraine deposit. Above this they become gradually concealed, as it seems, beneath lighter detritus, over which the stream runs for some way, and which passes into a great fan-deposit stretching across the valley from a lateral gorge on the east just below Bimphedi. Here the main branch of the stream runs upon rock at a much lower level, passing by a steeply cut channel along the west side of the valley. No great blocks appear in or upon this diluvial fan.

The case was not a little complicated at first by the fact that, along the whole valley of the Rapti and up to the crest of the Chessa garhi ridge in which it rises, no gneissic rock was observed in place. The first rock of this kind crossed on the road is some way down the northern side of the ridge. The strike of the rocks, however, would take this gneiss into the ridge east of the road well within the head-waters of the Rapti; and from this source, it must be presumed, all the aforesaid erratics were derived. The highest point of the watershed of the Rapti must be under 7,000 feet.

It would hardly have occurred to me to question the glacial origin of those immense boulders had I succeeded in finding any confirmatory evidence of glacial conditions in the higher mountain region. If the Rapti valley were ever occupied by ice, the whole country to the north must have been in a similar state. Yet I have to record that throughout the rest of my trip I failed to find any symptom of such conditions. Thinking that the valley deposits of Nepal would be younger than the glacial period, and might cover its most characteristic remains, I searched for such at the deepest point of erosion, about Kátwaldár, but without success. I was more surprised, and should have been so independently of the suggestion in the Rapti, to find no signs of glacial action in the Trisal-ganga valley at Nyakot. This is one of the great rivers, draining from the Gosain Than, a peak of over 26,000 feet in elevation, and it must now be fed by immense glaciers: yet in a length of six miles, from Nyakot to Debi ghât, I could find nothing to suggest glacial action. It is true the same excuse would apply here as in Nepal; this portion of the Trisal-ganga valley is occupied by deposits, well stratified and with peaty layers very similar to those about Katmandu, the river only touching rock at a few points; still it were marvellous that no trace should be seen of such a glacier as must have lain here had the ice ever advanced to Etoundah.

Despite all this want of confirmation, I cannot declare finally against the glacial origin of the Etoundah erratics. I know that torrents can do wonders in the way of moving large masses. But it does not appear that the Rapti can now stir such blocks as these, much less pile them together as they are at Etoundah. The great block noticed in the Churiaghati pass may be a straggler from the Etoundah rocks, though I could not see any like it on the northern slope of the range.

I trust that these crude notes will be of some service in guiding future visitors to Nepal Even incorrect suggestions may lead to observations that would otherwise have remained unnoticed.

H. B. MEDLICOTT.

August 1875.

THE RÁIGARH AND HINGIR COAL-FIELD, *by* V. BALL, M. A., F. G. S., *Geological Survey of India.*

(Second notice.)

INTRODUCTION.

The following account refers to the south-eastern extension of a very considerable tract of coal-measure and associated sedimentary rocks which is situated in the south-west frontier districts of Bengal, and some of the north-eastern districts of the Central Provinces. The limits and consequently the contained area of this tract are at present imperfectly known, but not improbably the latter exceeds 5,000 square miles. To the whole the name south-west frontier coal-field might be given; but for convenience in the description of certain portions which admit of separate treatment, such names as Bisrampur and Ráigarh—Hingir have been employed in previous accounts.

The name Ráigarh—Hingir was first adopted in 1871 as being less likely to mislead than the old name Gángpur,* no portion of the field being in Gangpur proper. The extension of the coal-field, as ascertained during the past season, has not rendered any further change of name desirable, the States of Ráigarh and Hingir being sufficiently centrically situated in the now known area to furnish a suitable local name; but the fact that the area so indicated is not an isolated coal-field should not be lost sight of. To the west, through Udipúr, the coal-measures or their associated rocks spread continuously to Korba in Bilaspur, while to the north, through Sirguja, the connection is unbroken up to Rewa and the borders of Mirzapur.

The Talchir coal-field,† though quite detached, is only a few miles distant from the most eastern points of our field, and may not improbably have been at one time connected with it.

The area occupied by that portion of the coal-field to be described in the following pages has a very irregular outline. Save for two narrow prolongations which extend to the east of the Ebe, it may be said roughly to commence in the angle enclosed between the Ebe and Mahanadi rivers a few miles to the north-west of Sambalpur. Thence it spreads in a north-westerly direction, the southern and south-western limit being defined by a well marked and in part faulted boundary. On the north-east, for about twenty miles, the boundary has only been partially examined, but sufficient is known of it to show that it is of an unusually complicated and obscure character. Originally it is not improbable that the extension of the Barákars was limited by the tolerably regular cliff of a low plateau of metamorphic rocks; but at the present time a considerable thickness of a newer series of rocks laps over this boundary and forms the hilly and difficult country of northern Raígarh and Hingir, thus concealing the edges of the Barákár rocks.

The reasons for supposing the Barákars not to have extended much further north are, that in a line with the bounding, uncovered metamorphics of the north-eastern corner of the field, exposures of the same rocks are found at intervals, as we proceed westwards, paving the deep-cut valleys between the ranges of upper sandstones.

How far these upper sandstones stretch northwards through Serapgarh is not known. It is possible that they conceal some small detached basins of Barákars. Thus far for twenty miles of the northern and north-eastern boundary, but for thirty miles further, until Rabkob on the Mand in Udipúr is reached, no northern limiting metamorphic rocks have been met with as yet.

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* Records No 4, 1871, p 101. All previous notices of the field will be found mentioned in that paper.
† Described in Mem G S. I., vol. I.

In the present account the coal-measure rocks which occupy the valley of the Mand and stretch thence to Korba are not described, as they have not been fully examined. They extend over a considerable area and contain many seams of coal.

I.—GENERAL GEOLOGY.

The rocks which occur within and in the vicinity of the coal-field belong to the following series and groups :—

Metamorphic Series.
Vindhyan „
Talchir „
Damuda „
Barákar Group.
Upper sandstones or Hingir Group.
Laterite.

The rocks of the metamorphic and Vindhyan series, which surround and underlie the coal-field, are not described at present, as the examination of them has been limited to the immediate vicinity of the field, and no general exploration of them has been yet attempted.

The Talchir series does not in this area attain any great thickness. Probably 250 feet is its maximum, but this estimate, in the absence of reliable *data*, is, it must be admitted, purely conjectural.

The rocks constituting the Barákar group are, I believe, of much less thickness than in the Damuda valley coal-fields; but there are no sections which would justify any definite statement.

The upper sandstones, for which the temporary and local name of Hingir group is used without prejudice to their future relegation under one of the titles used for similar rock elsewhere, may in places exceed 1,000 feet, but that is, I believe, a fair average. It has been arrived at from the measurement of horizontal beds from the level of the Barákars to the tops of the highest hills.

The thickness of the laterite seldom exceeds 60 feet. Generally it is much less.

II.—TALCHIR SERIES.

Within the area under description, the rocks which belong to the Talchir series do not anywhere attain any very great importance either as regards their thickness or the area occupied. As to the amount of the former, only an approximate and very rough estimate has been offered, no measurable section being exposed. Of evidence of faulting along the boundaries, except in the case to be hereafter mentioned, there is none. On the whole, it would appear that the representatives of this series merely occupy originally shallow and more or less detached depressions in the metamorphic rocks, and before any marked disturbance or denudation took place, were covered up and overlapped in most instances by the Barákars. One well marked case, at least, occurs, however, where Talchirs are immediately superposed by the upper sandstones, no trace of intervening Barákars being found.

In their lithological characters the Talchirs of this area conform closely to the well-known types, as will be seen from the following detailed descriptions.

For purposes of reference it will be convenient to refer to the several areas of Talchir rocks which occur along the margin of the coal-field by the names of the principal villages or rivers within their limits. Thus denominated they would stand under the following heads :—

SASUN—REMRA. This area occupies an irregular strip of country which stretches from a few miles east of Sasun* westwards to beyond Remra, in all for a distance of about twenty miles, and with a breadth of from three to six miles.

* Sasun is about eight miles north of Sambalpur.

In the neighbourhood of Sasun the rocks are much concealed by alluvium and laterite, and the exact position of the eastern boundary is from this cause somewhat uncertain. Both to the north and south of Sasun short sections of sandstones and shales are seen. Some of the beds of the former are tolerably thick, and one, a bluish-grey fine-grained rock, has furnished both building stone and material for vats used in lac manufacture. So far as it is seen, the boundary appears to be quite natural, following the irregular edges of the basin of deposit. West from Sasun, and on both sides of the Ebe, laterite conceals the Talchirs to a very considerable extent; though in this particular section of the country it is not abundant on the older rocks. There is sometimes, for several miles together, a most remarkable coincidence between the Talchir-gneiss boundary and the edge of the terrace-like spreads of laterite. So much is this in some places the case, that one can follow the boundary with the eye from a distance by means of the raised banks of laterite which terminate abruptly at the junction of Talchirs and gneiss. Of the cause of this I am at present unable to offer even a plausible explanation, and must therefore confine myself to the simple record of the fact.

The greater part of the bed of the Ebe, where it traverses these rocks, is one unbroken waste of sand; but there is a short section of sandstones and shales, with a dip of 8° – 15° to north-north-east, at the bend near Mangalpur. Here, too, in the bed of the channel, there is a boulder bed, the boulders in which are not very numerous nor of large size, but they can be seen sticking out of the silt here and there underneath the clear waters of the river.

In the country to the west of the Ebe so complete is the covering of laterite, that exposed outcrops of Talchir rocks are only very occasionally met with. In the eastern branch of the Kadam river at Gorgoda and Bodopali, and in the western at Binki and Bolunda, there are short sections, and the existence of a spur of metamorphic rocks running into the main Talchir area is rendered apparent. Half a mile north of Binki there are seen, in the high ground, shales and thin sandstones with a dip of 30° to north-east which has been caused by some very local disturbance.

At Remra (Remda of map) there is an inlier of metamorphic rocks whose boundaries are much concealed by laterite. From this westwards, the Barákars, which first appear overlying the Talchirs at Telunpali, gradually lap over, and before Borkhol is reached all traces of Talchirs at the southern boundary have disappeared. This total disappearance is, however, probably not exclusively attributable to overlap, as the boundary appears to be a faulted one, and a portion of the originally existing Talchirs may have been cut off. In the stream west of Dagarmunda the Talchirs for a short distance dip away from the gneiss at an angle of 60°.

A small outlier from this area of Talchirs exists in the valley of the Ebe near the villages of Taldi and Terda. The rocks seen are shales and sandstone.

This area covers something under one square mile, and was in all probability, judging by the character of the surrounding country, originally, as it is now, quite detached from the main mass.

KIRARAMA—PUTRAPALI.—Some eight miles to the north of the strip of Talchirs mentioned above, a second spur-like eastern prolongation of the field crosses the bed of the Ebe. Although Barákars are the principal rocks seen, indications of underlying Talchirs are not wanting at the margins. The first of these is at Kirarama. The principal rock is a boulder bed which is exposed at the foot of some small laterite hills to the east of the village. The boulders consist of jasper-conglomerate, quartzite, &c., all of quite foreign origin. The [illegible] is not improbably natural, the beds appearing to rest against hornblendic [illegible] of which is seen in the bed of the river. To the south and west the boun[illegible] concealed by laterite.

Apparently disconnected from this patch, Talchirs again crop out from beneath the Barákars in the bed of the Ebe below Ramesur, where there are green sandy shales with a low dip to north-east. Further east, in the village of Patrapali, sandstones come to the surface. To the north-east of that village, in heavy jungle, there is a ridge of pseudomorphic quartz which is not improbably connected with some faulting, but I failed to discover its character owing to the laterite covering. South-east from Patrapali, along the boundary, small outcrops of shales are seen at various points; and beyond Burimal, in the high ground, there are some considerable lenticular masses of limestone included in the beds of silt. Further east from this, detailed examination was not continued, but Talchir rocks were observed at Bursipali and Rurimoul.

RAJPUR.—On the northern boundary of the above mentioned spur, Talchir rocks appear in the vicinity of Rajpur, especially in the Godadia near its junction with the Baisunder, where there is a short section of shales and boulder bed, the latter resting naturally on gneiss. In the Baisunder, too, close to the junction, there are some sandstones with a dip of 5° to the south-west. In the bed of the Ebe the rocks are for the most part concealed by sand; but at Degam, on the western bank, there are short outcrops of shales and sandstones.

To the south-east, at Singaboga, some fine sandstones and shales are exposed, otherwise there are no other outcrops, and it would appear that at Chaltikra the Talchirs are completely overlapped by Barákars.

GARGANBAL.—Further north a narrow strip of Talchirs occurs on the boundary nea Garganbal. The lowest bed is generally formed of arkose, as I found to be the case a littl further north at Kosira on the Baisunder.* It rests naturally on the gneiss.

SAMBULPURI.—Passing now to the southern boundary of the field, a narrow strip of Talchirs is met with between the villages of Jamga and Laka. In some places, as to the south-west of Badpali, they dip away from the gneiss at a high angle. Sambalpuri is situated at about the centre of the area, and in its vicinity are the best sections. In some the beds dip at a high angle from the boundary.

A little beyond Laka these rocks are overlapped by Barákars, which are again, themselves, covered up by the upper sandstones.

Still further west is the area which may be conveniently indicated by the name of the river.

KURKET.—On the east and north the Talchirs of this area are bounded by the upper sandstones. Possibly the eastern junction may be faulted, but it has not yet been fully examined. On the west they are bounded by Barákars and on the south by gneiss. Close to Lotan there is a fine boulder bed.

III.—DAMUDA SERIES—BARÁKAR GROUP.

In describing the Barákar rocks of this field, we have to deal with a number of detached or semi-detached areas. Those on the north have been partially or fully described in the already published report on the Baisunder and other river sections, and the area in the Mand valley, and thence westwards, has only been partially examined. As neither it nor the Baisunder section were visited during the past season, they will not be alluded to further

VALLEY OF THE EBE AREA.—Commencing on the extreme east of the known extension of this area, a narrow strip or spur of Barákar rocks is found in the vicinity of Lupunga, where they are horizontal and much concealed by superficial deposits. Towards the north, the junction with metamorphics, as seen at Romali, is quite natural, the Talchirs being com-

* *Vide* Records Geological Survey, India, 1871, p. 10[illegible].

pletely overlapped. On the south, however, there are indications all along the boundary, from Bursipali to the Ebe, of underlying Talchirs.

Proceeding westwards, the northern boundary is found to strike obliquely across a great loop bend of the Bonum river at Chalitikra, but the lowest seen sandstones there seem to be Talchirs. Between this loop and the Ebe, the country is very hilly and uneven. The rocks are coarse sandstones and conglomerates, some of the beds being of considerable thickness. As seen in the neighbourhood of the old fort of Rampur, in the Ebe section and in the country further west, some of these rocks resemble the upper sandstones of the Hingir group; but after full examination I am inclined to refer them to the Barákars. Brown hæmatite iron ore is very abundant, and especially so to the east of Ramesur. It does not appear there, however, to constitute any definite continuous bed, but to occur rather in concretionary nests and bands in the sandstones. Fragments of ore from this source spread over a considerable surface, and give the appearance of an abundant supply, especially in the valleys where they have accumulated for ages. Iron is manufactured at Chalitikra, and was formerly at Rampur, where there are still considerable heaps of slag to be seen.

Some of the conglomerates seen here consist of pebbles in a matrix which is barely sufficient to bind them together. As this matrix is often removed at the surface, the hills of conglomerate look simply like piles of loose stones, not a sign of consolidated rock being apparent. The bed of the Ebe affords no continuous section of these rocks, the few outcrops being for the most part separated by long stretches of sand. As, moreover, the beds are here horizontal, or nearly so, nothing of importance regarding their thickness can be made out. Opposite the mouth of the Bonum river, a cliff of sandstones covered by conglomerate rises to a height of from 50 to 60 feet. These rocks, though not exactly like the usual types of Barákars, from their position and physical relations, should, I think, be referred to that group. The rocks of this horizon can be traced north and south over about ten miles, from the neighbourhood of Cherla to Bograchaka; they form long low ridges with a very slight dip to the west, which carries them under the more typical Barákars containing coal and some ironstones which are about to be noticed. Between the Ebe and the boundaries of the upper sandstones underneath which the Barákars disappear, rivers and streams occur in abundance, but in two only have any traces of coal been met with.

THE LILLARI RIVER.—This river, like many others, takes its rise close to Hingir, and joins the Ebe, after a course of about twenty-five miles, near the village of Balput. Following it up from its junction, in the first two miles or so, metamorphic rocks only are seen, but beyond them Barákar sandstones are exposed, and appear at intervals up to Durlipali, where there is a seam of carbonaceous shale and coal, of which the following is the section, *descending*:—

Top denuded.

		Ft.	Inc.
1	Slightly coaly blue and black shales	9	0
2.	Black carbonaceous shale with flaky coal	6	6
3.	Concretionary blue shales	1	3
4.	COAL (*Vide* Assay, p 120) contains much iron	2	6
5.	Blue concretionary shale with coaly layers towards top and bottom	5	6
6.	Slaty carbonaceous shales, portions coaly ..	3	0
7.	Ditto ditto the coaly portion confined to thin layers of 1-3 inches thick	12	0
[illegible]	Blue concretionary shales	1	6
	COAL fair (*Vide* Assay)	1	0
	[illegible] concretionary shales	2	0

Base concealed.

Coal from No. 4, brought to camp, burnt indifferently, leaving a considerable ash. From No. 9, the coal is much better; a *garah* full when roasted gave out a luminous flame 18 inches long (with a 1-inch diameter burner) which lasted for an hour. Most of the residue was partially caked. Higher in the section there is a bed of tesselated ironstone which seems to be continuous at that horizon, being seen again at Choakani, five miles to the north, and also in the intervening country. North of Kodaloi there appears to be a second ironstone zone which includes a better quality of stone. This zone is also seen further south, one mile to the west of Rugonathdera. The rocks throughout this region are much concealed by laterite.

Seam.

Two miles further up the stream, near Khairkoni, the top 2 feet of a coal seam are exposed. For four miles further, up to Chamri-mahal, the bed of the river discloses a much broken section of sandstones and carbonaceous shales, which in places roll slightly, but are otherwise horizontal. Beyond this the sandstones of the Hingir group are alone found.

Seam.

BAGDIA RIVER.—About half a mile from Ailepur (Lukenpur) the top of a seam is seen in the river. Owing to water and shifting sand I could do no more than prove the existence of at least a foot of fair coal which burns freely, leaving a flaky ash. What the total thickness of the seam may be it is impossible to say at present. In the country to the east there are some ridges of ferruginous sandstones which may, perhaps, be in part prolongations from the main area of upper sandstones, but I was unable to separate them from the underlying Barákars with any degree of certainty. Leaving for the present the description of the strip of Barákars which extends from this neighbourhood through Borkhol along the south of the field, that which occurs along the north-eastern boundary may be most conveniently disposed of. Close to Ratakand, a small village on the Godadia, the Barákars, which further south are covered up by the sandstones of the Bilpahari range reappear, and form an irregular strip which is continuous up to the Baisunder, where the coal-measures, described in the previously published notice of this field, occur. On its eastern side, the Barákars occupying this strip rest naturally upon the metamorphic rocks, an arkose bed being not unfrequently found at the base. On the western side the irregular outline formed by the foot of the upper sandstone highlands of Hingir constitutes the limit of exposure. In the river at Dúlúnga, to the south-south-west of the

Seam.

village, there is a coal seam of which the following is a section of the portion seen, *descending*:—

		Ft.	Inc.
1.	Black and grey shales		10
2.	Hard stony COAL		6
3.	Flaky COAL		2
4.	Grey and black shales		4
5.	Flaky shales, coaly in parts	1	10
6.	Blue and grey shales	1	0
7.	Stony COAL and black shales	1	4
8.	COAL		4
9.	Stony COAL and black shale		7
10.	COAL		7
11.	Shale	1	4
		8	10

Further down the stream some higher layers of carbonaceous and coaly shale belonging to the same seam are imperfectly exposed.

To the north of the village there is a seam seen, at the road crossing, which contains about six feet of coaly shale and coal, the dip being 5° to south. In the section of rocks below this, that is to say, further up the stream, the boundary is seen to be perfectly natural; gneiss being exposed in the bed and sandstone in the overhanging banks. From this northwards the relations of the rocks are for the most part obscure and the western boundary is very intricate. In the Barákars to the south of Kiripsira, black shales and ironstones occur. On the Garganbal and Bagbura road, east of the boundary, in the first stream crossed, there is a bed of arkose, which seems to be detached from the field. Beyond it for the next mile or so, the granitic gneiss rocks which occasionally appear are much covered by loose boulders which in their miscellaneous and foreign character resemble those found in the Talchirs. In all probability they were derived from a Talchir boulder bed of which no other trace is left now.

SOUTHERN BOUNDARY.—Passing now again to the south boundary, at Borkhol. In speaking of the Talchirs it has been pointed out that they disappear on the boundary at this point, being much overlapped, and having probably been in part cut out by a fault which appears to have formed the present southern boundary and limit of the field. At Singapur the area occupied by the Barákars does not exceed about half a mile in width, and as they rest nearly horizontally on Talchirs, the evidence of extensive overlap by the upper sandstones is complete. West from Borkhol, where the Talchirs are not found on the boundary, their apparently diminished thickness might be attributed to the fault having cut out lower beds, but here it is quite clear that, unless there has been great natural and original thinning out of the upper beds of the Barákars which are seen in the Ebe valley, their edges must be completely overlapped by the upper sandstones.

From Borkhol the faulted boundary runs in a steady north-westerly direction for nearly forty miles, and with it for thirty miles, a valley which presents a wonderful degree of uniformity throughout. On the one side, outside the fault, are ranges and sometimes low ridges of metamorphic or other old rocks, on the other the scarp of the sandstones forming the Hingir plateau. The bed of this valley being coincident, or nearly so, with the base of the upper sandstones, the Barákars, and sometimes the Talchirs, form the floor. Although many rivers and streams cross the valley at right angles, there is such an accumulation of superficial deposits, that sections, showing the character and relations of the rocks are of extreme rarity. The bottom of the valley, almost throughout, may be described as one succession of *paddy* fields. The origin of this state of things is quite obvious. The valley, in the first instance, scooped out by lateral streams along the faulted junction, has subsequently served as the repository of the solid substances brought down by the rivers, which, coming from the highlands of comparatively soft sandstones, find themselves suddenly arrested by the metamorphic rocks through which they have only been able to cut narrow gorges.

At Borkhol itself no rocks are exposed in the valley; but further west, south of the village of Durga, sandstones and gneiss are seen in close proximity to one another, though no actual contact is exposed. To the west of Kutrapali there are some ferruginous Barákar sandstones with ironstones, which also extend northwards up into a bay to the north of the village. Proceeding in the same direction the same rocks are met up to Dibdorah, with the addition, at that place, of coal which crops out underneath the waters of the Hingir river. An excavation which I had made in this seam proved a thickness of at least 6 feet 6 inches down from the denuded surface. Of this thickness, all, except the lowest foot, consists of very fair-looking coal. So far as appearance goes, it is certainly the best which I met with in the field. The dip is about 5° to north-[illegible] east, or from the boundary. What the total thickness may be I had no means of ascertaining.

Seam.

Higher up the river, close to the foot of the falls over the upper sandstones which are described on a following page, the Dewan of Kodibuga pointed out to me some fragments of carbonaceous shale which he said had been there for several years. Whence they came I am quite uncertain. There may possibly be a seam at the foot of the falls covered up by water and fallen blocks. Certainly in its higher reaches the river does not cross any Barákar rocks, and I found no trace of carbonaceous matter in the stream above.

Between Jhargaon and Dibdorah, the sandstones, wherever seen near the boundary, as also the coal at the latter place, exhibit no trace of great disturbance at their edges, having, apparently, when faulted, gently subsided into their present position. Neither at Dibdorah nor Jogidhipa are junctions disclosed by the rivers. Between Dibdorah and Jogidhipa the Barákars are of the same character as those between the former and Jhargaon.

At Jogidhipa, the scarped hills, which further east marked the limits of the upper beds, locally die away, and physically it seems possible that the rocks exposed for some distance to the north might be Barákars, but lithologically they appear to belong to the upper group.

Continuing along the valley we find at Lipuspali, north of the village, dark colored sandstones which appear here to form the base of the upper series. No Barákars are seen, though they doubtless exist under the alluvium. Before reaching Manwapali, Talchirs are found to come in again, forming a narrow strip along the boundary and leaving but very little room for the Barákars to occupy.

In the Supnai west of Bhogra (Basunpali of map*), at the base of the section, there is a short thickness of sandstones, apparently Barákars, which dip from the boundary at an angle of 30° to north; the overlying rocks, too, are also locally disturbed. Between Bhogra and Sumbulpuri the position of the Barákars is marked by ironstones, which are seen near the village of Badpali. At Sumbulpuri, if the coarse grits seen in the river section dipping at angles of from 30° to 45° from the boundary be not referable, as seems probable, to the Barákars, then that group must be here reduced to very narrow limits. At Danot the upper rocks come close to the north of the village, while Talchirs crop out on the south; but there is room for a small thickness of Barákars. In the Kelú section between the gneiss on the one hand and brownish-red upper sandstones on the other, a concealed interval affords room for both Talchirs and Barákars. One short outcrop of Talchirs is seen close to the road crossing.

Had I not known something of the upper reaches of the Kelú, the occurrence of fragments of coal in the bed of the river, as it issues from the upper sandstone hills, would have been a puzzle involving much fruitless search. It is evident that these fragments have travelled from the seams which the Kelú traverses far to the north near Tamar and Jhargaon.

Between Laka and Cheripani, an interval of only about 150 yards exists between these upper sandstones and the Vindhyan quartzites. In this interval laterite and a recent conglomerate are the only rocks seen. Further west from this I did not meet with the slightest trace of Talchirs, and the lowest sandstones seen are not, I think, Barákars, so that both series are again most probably cut out by the fault which hence westwards runs between quartzites of Vindhyan age and the sandstones of the Hingir group.

GARJAN AREA.—To the north, under the Garjan hill in Hingir, some carbonaceous rocks, probably Barákars, are exposed in the streams. This area has not been examined as yet in detail.

NORTHERN RAIGARH AREA.—This is an area of Barákar rocks of which upwards of 200 square miles have been examined. It is situated in the north-eastern corner of

* The names of all the villages in this part of the valley are misplaced on the map.—(Atlas Sheet).

Báigarh. On the east, south and west it is surrounded by hills formed of the upper sandstones, under which the coal measures pass.

To the north the limits have not yet been ascertained, but from the sections which have been examined, and from the general physical structure of the country, it is probable that, with a few exceptions in the valleys, where contacts of the Barákars with the underlying metamorphics are exposed, the edges of the former are overlapped by the upper sandstones.

In this central area, the Barákar rocks, which from their position are probably the top measures of the group, differ materially from those met with in the Ebe valley to the east. Instead of coarse sandstones and conglomerates, there are fine sandstones with much carbonaceous shale and some coal. In all probability the coarser rocks occur below, and indeed to the north some of them are seen cropping out towards the boundary. In the Baisunder section†, on the other hand, it would appear that the coarser rocks never were deposited, as only a small thickness of sandstone and arkose intervenes between the carbonaceous shales and gneiss.

In the western part of our area the Karket river collects the drainage and affords tolerable, though much interrupted, sections.

KARKET RIVER SECTION.—That portion of the Karket which traverses the upper sandstones will be found described on a following page. In so far as the Barákars are concerned, it is only necessary to describe the descending section which is exposed between Báiámundá and Karamakel.

The highest rocks seen are some sandstones with three bands of carbonaceous shale, which measure respectively 2'., 3'. and 3'. 6.", the dip being 5° to south-west, which carries them under the horizontal upper sandstones. Some ironstones seen to the south of Báiámunda, but not exposed in the river section, not improbably constitute the top beds.

Not far from the mouth of the Katang stream the top of a coal seam is exposed which measures about one foot. For about half a mile north of the Katang there are massive sandstones, the relations of which to the more typical Barákars are somewhat obscure: at first it appeared probable that they might be upper beds resting in a flat synclinal, but subsequently seen cases of similarly situated and similar rocks, suggested that they were only locally interpolated beds.

Beyond these again there are thin bedded sandstones with shales more or less carbonaceous, having a low dip to south. Less than half a mile to the south of Suadera there is a coal seam which contains only eight inches of good coal with a dip of 5° south-west.

Seam

From this up to the mouth of the stream which rises in the Duldulla H. S., the only rocks seen are thin bedded sandstones and carbonaceons shales, which vary a good deal in the direction of their dips on either side of south, but not much in the amount, never ranging above 10.° There is nothing that can be called coal exposed in this portion.

At the stream, however, there is a seam of which the following is a section :—

	Ft	Inc.	
Massive sandstone, about	25	0	
Shale		?	
COAL	1	7	
Shaly parting	0	9	
COAL	0	5	
Carbonaceous shale with coaly layers	4	8	
COAL	3	0	seen.
Base hidden; dip 3° S. S. E.			

The overlying bed of sandstone is seen lower down the river to break up into several smaller ones in consequence of the interpolation of carbonaceous shales; thus bearing out the view taken above of the bed seen near the mouth of the Katang.

Further north from this I did not continue detailed examination, but fragments of coal are abundant from the higher reaches, and the Barákars extend at least as far north as the valley surrounding Kurmukel (sheet 59 *a*, old series).

In the Katang stream, from Kassia to its junction with the Karket, there are carbonaceous shales with sandstones, and the massive bed previously mentioned. Some fragments of coal were seen, but no exposed seam could be found.

Throughout the country between the Karket and Pazar the rocks are much covered, and there is nothing of particular interest to be noticed.

PAZAR RIVER SECTION.—At the junction of the Barákars and upper sandstones, where this river enters a gorge through the hills to the south-west of Kasdol, the former show signs of local disturbance, and the bed, which is a few feet from the junction, dips away from under the overlying horizontal sandstone in a manner which is suggestive of unconformity. There being no actual superposition, this section cannot perhaps be considered conclusive, and causes other than original unconformity may have produced the present appearance. Taken in conjunction, however, with other evidence of unconformity to be given further on, this section assumes some importance. A short distance up the stream there is a seam of which the following is a section:—

			Ft.	Inc.
Sandstone	...	...	0	6
Shales ...	...	...	7	0
COAL ...	...	...	1	5
Black shale	...	...	0	5
COAL ...	...	...	1	0
Shales, portions coaly.				

For the remainder of this section up to Pondripani there are fine sandstones and carbonaceous shales, the latter with occasional layers of coal, as at Putrapali (8″) and at Pondripani (2″). There is much false bedding and interpolation in this section. In the Digi stream the section is similar. A seam of 6″ of coal is exposed at Deogur. The Kelu river section up to Tamnar also exposes the same kind of rocks with no coal of workable thickness.

The Kelu section beyond this up to Khara was described in my previous report. Resuming, therefore, at that place, we find that for nearly two miles hardly any rocks are seen, but beyond that there is a tolerably continuous section of sandstones and carbonaceous shales The first seam measures, descending, dip 5° south-west:—

				Ft.	Inc.
COAL ...	...	...	...	6	0
Shales ...	...	...	...	3	6
COAL ...	...	...	...	1	0

The coal is probably of rather inferior quality, but in its weathered and water-logged condition it is not possible to form a conclusive opinion. The next seam of any importance measures about 17′. The coal is in thin layers of less than a foot, alternating with shale, dip south-south-west. Beyond this there appear to be some other seams; but they are not well exposed. North-west of Pelma two flat seams are exposed. Their thicknesses seem to be about 6′ and 4′ respectively. The coal may be of fair quality. These seams are also seen in the broken ground east of the river, where the thickness may be somewhat more. For three miles further I followed this section (into Sheet 52), the Barákars continuing steadily

in the bed of the river, while the hills on either side were of the upper sandstones. Fragments of coal were still to be seen at the furthest point reached; but from the abundance of gneiss and jasper-conglomerate pebbles, the metamorphic rocks cannot be very far distant. The jasper may not very improbably be derived from Talchir beds.

The Pelma-Milupara valley is one of several along this frontier where denudation has removed the upper sandstones, thus forming a vast amphitheatre in which Barákars form the floor. A considerable accumulation of alluvium occurs in this valley; it is much cut up by ravines, and consequently difficult to traverse. As it was impossible to take the camp beyond Milupara, much time was wasted in going to and fro. To draw a satisfactory boundary at the foot of the hills would require close and very detailed examination.

BENDIA RIVER SECTION.—In the portion of this river not previously examined,* between Kornkel and Janjghir, for the first three miles the rocks are much covered, after which there are coarse sandstones with a succession of seams containing coal in bands of from 2′ to 3′. None of these seams are well exposed, as they are for the most part flat, and it is impossible to speak decidedly of their value. It is not, however, at all improbable that good coal in workable quantity may exist. At Janjghir the Barákars abut against gneiss, and are in places covered by upper sandstones which cross the boundary. In some cases the bottom beds resting on the gneiss in the Janjghir valley may be Barákars; but the cases are doubtful. To the west of the village a pebble conglomerate bed can be traced from off the metamorphics on to undoubted Barákars upon which it appears to rest unconformably, but the section is not quite clear. In one place in the river it is seen distinctly overlying a coal seam with associated Barákar sandstones. This seam measures—

	Ft	Inc
COAL, about	0	8
Parting	0	3
COAL	1	0

I think the conglomerate must be referred to the upper series.

In the bed of the stream on the hill side, at the head of this valley, I found some fragments of black shale, which appear to have come from the upper beds. As will be noticed further on, a similar case occurs to the east, in the valley of the Bendia.

From the preceding it will be seen that there are no *data* sufficient for forming an opinion as to the total thickness of the Barákars, but that there is strong evidence of great irregularity of deposit.

On the prospects of coal being found in useful amount, I shall speak in the section on economic resources.

IV.—UPPER SANDSTONES, OR HINGIR GROUP.

Resting upon the Barákar rocks is a group of beds differing from them in their lithological characters, and containing certain fossil plants which have in no part of the country been found to occur in rocks of the Barákar horizon.

With rare, and perhaps even somewhat doubtful exceptions, this group does not include any carbonaceous deposits. In the fossil plants the carbon has been all removed and replaced by iron

In some of the sections described on previous pages evidence is given of the extensive scale in which the Barákars have been overlapped by these younger rocks. At many places along the southern boundary of the field, as, for instance, at Singapur and Borkhol (*vide* p. 108) the area occupied by the Barákars is reduced to very narrow limits. Again, near the Kurket

* *Vide* Records, 1871, pp. 105-6.

these upper rocks rest immediately on Talchirs, and along the northern boundary not unfrequently upon gneiss.

Unconformity.

Although the junctions between these rocks and the Barákars often appear to be quite conformable, certain observations seem to indicate that some unconformity between the two does exist. No actual section exhibiting unconformable superposition can be adduced, however. The nearest approach to it is perhaps the case above mentioned, where, close to Janjghir, a pebble conglomerate was traced off the gneiss on to Barákars upon which it appears to rest unconformably, but owing to some false bedding, the section is not quite clear, and should not, perhaps, be regarded as crucial. In the Pazar river section (page 111) there is the already noticed case of disturbed Barákars occurring close to the junction with the massive horizontal upper sandstones.

Passing from these individual cases, which afford evidence of only doubtful value, to the more general relations existing between the upper sandstones and the Barákars, we find that, taken as a whole, the latter exhibit an amount of rolling and disturbance of which the upper beds show no trace whatever.

The great amount of false bedding in the Barákars, noted both in this and the previous report, and the overlap, are quite sufficient to account for the fact that the beds of Barákars appearing from underneath the sandstones vary much in character in different parts of the field. At Lipuspali, for instance, there is a coal seam only a few feet below the red shales. Yet no sign of this coal seam appears in any other section. But when the facts observed in the tract of country indicated as the northern Ràigarh area (p. 109) come to be examined, it is difficult to imagine any cause other than unconformity as being able to produce the relations which exist there. Denudation has in that part of the country cleared away the upper rocks and formed an extensive basin where upwards of 200 square miles of Barákars are exposed. Numerous more or less continuous sections of these rocks are afforded by the rivers which run from north to south; but the best is that in the Kurket. In that river from south to north there is a steadily descending section, which is sometimes complicated by local rolls, but which must represent several hundred feet in thickness. The crumpling and rolling and the dips,—the latter in places attaining as much as 10°—are incompatible with the idea that these beds are merely in their original position of deposit on a sloping surface. Several of the coal seams dip at angles of 5,° which, small though it be, can scarcely have existed at the time of deposit. From its very nature and generally accepted origin the coal must have been at first horizontal, or nearly so.

In the surrounding rocks which form the ranges limiting the basin, and in three inlying hills or groups of hills known as Gid, Duldulli, and Kolam, no evidence of similar rolling and crumpling is apparent, while the sections, so far as they go, induce the belief that these outliers rest on the edges of different portions of the Barákar succession. From the interpolation and false bedding, which, as has been alluded to, characterise these Barákar rocks, no actual conclusion could be drawn from observations on the difference in character of individual beds which are immediately covered by the upper sandstones. Indeed, the overlap alone would be sufficient to account for such differences as have been observed. It is therefore necessary to confine the evidence for the unconformity to the more general characteristics of the two series, all small sections being, for the above given reasons, unreliable.

Examined closely, the upper sandstones exhibit no signs of disturbance and appear to be quite horizontal. On some of the scarped ranges where the view takes in several miles, a slight southernly trend can, however, be made out, but no rolling corresponding to that in the Barákars at the base. Whether the rolling and crumpling in the thin beds is in any degree due to the pressure of the great mass of hills—which would in that case have been produced

subsequently to the denudation—may perhaps be a subject for speculation; but even supposing that a certain amount of disturbance may have been due to this cause, the general steady succession of beds from south to north, and the fact that the sandstones rest upon different members of that succession in different places, must, I think, be regarded as indicating a period of disturbance and denudation between the deposition of the two series of rock. It may be added that whereas we find in the case of the Janjghir section, already alluded to, the upper sandstones passing from Barákars (at the base of the group) on to gneiss, the same rocks cover up the highest members of the Barákar succession which are exposed on the southern limits of the Barákar area between Bijana and Deogaon.

In their lithological characters these beds differ in a marked degree from the Barákars. The first thing which strikes one about them is that they almost invariably present a reddish aspect from the freely disseminated iron. Be they conglomerates, sandstones, or clay shale, the presence of iron is generally prominently apparent. The soil, too, which is derived from their decomposition, is nearly always red and sandy. Notwithstanding this, ironstones of good quality are very much less frequently met with in this group than in the Barákars.

I have been unable to see that the beds of different lithological characters occupy any definite succession. The red clay beds particularly seem to have a very capricious distribution. Though not always present, they are generally found among the bottom beds of the group. Towards the top, too, they not unfrequently occur. In the centre they appear seldom. Often where one would expect to see them, they do not show the slightest indication of their presence. Conglomerates and sandstones alternate with one another without showing any regular sequence so far as I was able to make out.

The conglomerates consist chiefly of small rounded quartz pebbles, bound together in a sandy ferruginous matrix with a varying amount of felspar. The pebbles rarely exceed 6 inches in their greatest diameter, and sometimes they are uniformly, throughout particular beds, not larger than small marbles. Occasionally the pebbles are of gneiss. This is, of course, most frequently the case when the underlying rocks belong to the metamorphic series.

The sandstones vary much in texture and color, but really fine-grained sandstones are rare, and white, or even grey looking, rocks are of unusual occurrence. Sometimes beds occur, both in the case of conglomerates and sandstones, which it is not easy to distinguish from Barákars. In such cases traces of associated carbonaceous beds are anxiously looked for as affording an almost infallible test of the age. The beds of sandstones, as may be seen in the scarped sides of the hills, occasionally attain very considerable thicknesses, narrow partings of shale occurring at distances of from 20 to 40 feet. The most common form of sandstone is a rough brownish grit, which, even when under the constant action of running water, seldom shows a clean or smooth surface. Carbonate of lime is not often present in sufficient quantity to give rise to any marked form of chemical weathering. Mechanically formed pot-holes are, for some reason which I cannot explain, less common than in the Barákars.

Shales or clays, generally red and sometimes passing into ironstones, include all the remaining forms of rock found in this group. In one direction these beds show a tendency to pass into sandstones, but as I have said, fine grained sandstones, properly so called, seldom occur. Mica occurs in abundance in certain layers. With the exception of some white beds which are occasionally met with, all are ferruginous, some highly so; the latter are dense and heavy, but are seldom used as an ore of iron by the natives.

…ds of this group which have so far proved fossiliferous are the shales which …mentioned, and they are by no means universally so. The place where I

found fossils most numerous as regards individuals was in the Garjan hill in Hingir. Here, too, the number of species was the greatest, but it does not altogether exceed eight.

The following is a preliminary list by Dr. Feistmantel:—

EQUISETACEÆ.

Schizoneura ? = Damuda sp.
" ? sp.
Vertebraria Indica, *Bunb.*

FILICES.

Glossopteris Indica, *Schimp.*
" Browniana, Brogn. Var. Australasica.
" Sp.?
Pecopteris Sp. = Bunbury's drawing.
" Lindleyana, *Royle.*

The specimens of Vertebraria were met with at Girundla, Kodaloi, and on the Bilpahari.

The question of the correlation of these rocks with the groups elsewhere known in India is for the present reserved.

These sandstones cover by far the largest part of the area included in the field. Throughout the central portion no other rocks are met with, and to the north-east and south-west, only narrow strips of the older rocks are disclosed at the boundaries, and that for comparatively short distances. In the northern part of Ráigarh there is a considerable exposure of Barákars which is surrounded on all sides by these rocks, and so superficially separated from the Barákars of the Ebe valley on the east, and of the Mand on the west.

The eastern boundaries of these sandstones follow an irregular outline, which is in general well marked, and is more or less coincident with the limits of the hilly plateau country of Hingir. Possibly there may be some small outliers within the limits of the area colored as Barákar, but the often highly ferruginous characters of some of the pebbly beds presumably belonging to the latter, and the obscurity of the physical relations renders discrimination almost impossible.

The group of hills of which Sitaram and Bilpahari are the culminating points is situated at the northern extremity of the eastern boundary; the rocks seen there are sandstones and red shales, the latter containing *Vertebraria.* Some of the sandstones are highly ferruginous, and contain layers and plates of hardened and dense character which weather out on the surface into relief, as is commonly seen in the Pachmari sandstones.

At Girundla and Bindichua the same rocks prevail; they are generally horizontal, but at one place in the Lillari, south of the latter village, some local disturbance has given rise to a southern dip. The Bindichúa G. T. hill station well illustrates the tendency of certain beds of sandstone to weather into curious and grotesque shapes.

The rocks about Onkilbira, Komghat, and Pikol are all of the same character and call for no particular notice. The same may be said of those forming the hills to the east and south of Lakenpur.

Close to Borkhol, the Koilar river debouches from the hills; it is the first of a series which, rising in the highlands of Hingir, pursue a steady south course to the Mahanadi. As the rocks which they traverse, except near the boundary, are horizontal, the sections do not throw much light upon the general characters of the series. Ordinarily these rivers run in deeply cut channels in beds of coarse brown or red sandstones. These being water-bear-

ing strata feed the rivers all along their course, and the moist faces of exposed rock are the favorite growing place of a species of *Drosera*; all these rivers are perennial, and their constant flow of water makes them contrast with the rivers of the gneiss and Talchir areas which soon dry up after the rains, leaving wide sandy channels.

The general characters of the valley which extends along the boundary in a north-westernly direction from Borkhol have been described on a previous page. With the rocks which bound it on the north only have we to do at present. North of Jhargaon the road to Raini ascends over the scarp of red shales and sandstones; these are still better seen further west at Dibdorah, where there is a step in the Hingir river over which the waters fall, forming a most picturesque, and in the eyes of the natives sacred, cascade. Near the foot of this fall, as has already been mentioned, some pieces of carbonaceous shale were found, but none above.

At Jogidhipa the physical features are somewhat modified, as there is no distinct ridge or scarp on the Barákar boundary, but the relative position to the main boundary of the field appears to continue the same. From this westwards the red clays cease to occur associated with the basal rocks of the upper sandstones.

In the Kur or Chota Kelú, between Berapali* and Beramunda, there are brown and yellowish sandstones which sometimes contain pebbles, but there is no trace of the red clays. Their absence may be due to overlap of that portion of the series in which they occur, but I think more probably they were never deposited here. At Jamga* the Barákars are almost completely covered up by these upper rocks.

In the Supnai section from a point east of Jhargura to Bhogra* there are coarse ferruginous sandstones which are at first slightly inclined to the south, but as the boundary is approached, they dip in the opposite direction, and the bottom beds, some of which seem to be Barákars, dip at an angle of 30° to north.

In the Somkara and Bilaijor rivers to the east and west of Sambulpuri there are similar sections; in the latter the rocks close to the boundary dip away from it at as high an angle as 45°. Close to Badpali there are some traces of a local bed of red clay.

In the Kelú there is a long interval between coarse sandstones dipping at 20° north and the gneiss. Save for a small outcrop of Talchirs at the ghât there is nothing to indicate the character of the intervening rocks. Further north, these sandstones fall to the horizontal and are deeply channelled by the river. I have on a previous page indicated the origin of the coal fragments which are seen in the bed of this river.

At Donot, the edges of the upper sandstones form a distinct and prominent ridge close to and north of the village.

In the vicinity of Cheraipani the Talchirs and Barákars are apparently finally overlapped by the sandstones on one side, and cut out by the fault on the other; at least no certain sign of them is met with further west. They may exist, however, at the bottom of the narrow alluvial valley which is bounded by on either side quartzites and sandstones. At Delari (or Derali) sandstones dip at 30° to north-east. Just north of the village the lowest bed may possibly be Barákar, but I think not. To the south-east of the village these sandstones are seen within 200 yards of the quartzites.

From this westwards to the Kurket, and also to the north in the direction of Tumardi, the rocks which are exposed all belong to the upper series.

Kurket River Section.—At Rabo there is an interval of perhaps 300 yards between the gneiss and some beds of sandstone, which dip at an angle of 30° to 30° north-of-east.

* These names, as previously mentioned, are all misplaced on the Atlas Sheet.

[illegible]

What may intervene between these outcrops can only be conjectured, possibly Talchirs, but there is no trace of them to be seen. With regard to the sandstones, I think they must be referred to the upper series, though they are not unlike Barákars, which, indeed, I thought them to be when I saw them in 1871. The high dip is gradually lessened, until about a mile further north the beds become horizontal, and so continue with only local variations in dip for about five miles. In places the river runs in a deep cutting with walls twenty feet high. The sandstones are of the usual character, coarse ferruginous, sometimes with plates and layers of more highly ferruginous composition. They are often somewhat conglomeratic and not unfrequently pinkish in color. There is no sign of red clays in this section. From underneath these rocks at Baiamunda, as has already been mentioned, appear the Barákars.

To the west the boundary, leaving the river, passes along the foot of a range of hills which strikes north from Katangdi. At Nowagaon (Nowagud) these hills present a scarped face of coarse ferruginous sandstones with some red clay partings. These rocks have a general, though slight, dip to the south. Detached from this range, towards its northern extremity, is the Duldula hill which is formed of the same rocks.

The eastern boundary on leaving the Kurket, passes south of Baiamunda and then bends southwards to Jiringol. Between Balumar and Samaruma the red shales were again met with near the base of the series.

The Gid hill appears to be an outlier of these rocks, the continuity being broken on the south, but this is not quite certain, as the rocks are much hidden in the broken raviny ground. The principal rocks forming this hill are ferruginous sandstones and red shales, but at the base there is a considerable bed of white sandstone of doubtful affinities.

The character of the junction in the Kelú river section has been alluded to above; the upper sandstones, away from the boundary, are horizontal, or have a gentle dip to the south.

From this eastward as far as the Ambo hill the boundary runs along the foot of the scarp; this is well seen at Deogaon and Pariga. In the Garjan hill, I found the principal part of the fossils mentioned on page 115. The further extension of these rocks to the east has been noticed in my previous report, and it therefore only remains to describe their occurrence to the north so far as they have been examined in that direction.

At Janjghir and the valleys on either side of it, we find Barákars abutting against gneiss, the boundaries being more or less overlapped by sandstones and conglomerates which form the surrounding hills. These sandstones and conglomerates are, I think, referable to the upper group, but at the heads of two of these valleys, from 150 to 200 feet above the level of the top of the Barákars seen outside, I met with fragments of coaly shale in the beds of the hill-side torrents. At first sight this suggested the probability of Barákars occurring at the higher level, but another case, presently to be mentioned, seems to make it probable that carbonaceous shales do sometimes occur in the upper beds.

A glance at the map* will show the difficult nature of the country where these observations were made. Until the whole of the hill tract there has been examined, it will be impossible to speak with any degree of certainty on the subject. As rendering it more probable that the carbonaceous shale is from the upper sandstones, it may be mentioned that the fragments were much mixed with pieces of red shales which *may*, however, have come from a higher level.

The amphitheatrical appearance of the valley of the Kelú above Milupara has already been alluded to. Owing to the jungle and superficial deposits, the boundaries are much obscured, but at Hingjhar there are exposed some ferruginous sandstones and red shales

* On the one inch to a mile scale. In the accompanying sketch map the hill shading has been omitted.

resting upon ironstones, which latter are presumable Barákars. On the east of the valley, in the Sukti hill, there is a good section of these rocks.

Ascending from the village of Bajarmura, which is on red clays and sandstones, the path passes over whitish grey sandstones, which might pass lithologically for Barákars; above them near a bear's cave* is a band of black shales; this is at least 300 feet above the red shales of Bajarmura, and must therefore belong to the upper series.

Above this there were coarse ferruginous sandstones which continued up to the top of the hill. On the eastern side of the hill, at Khara, the Barákars extended up the side from 100 to 150 feet.

So far as they have been examined, these upper sandstones appear to constitute one group which is not susceptible of any natural sub-division.

V.—LATERITE.

In the course of the preceding pages the occurrence of laterite resting upon the older rocks has been occasionally alluded to. It is more particularly abundant on the Talchirs, and, as noticed on a previous page, its limits are curiously concurrent with the Talchir—gneiss boundary in the eastern part of the field. To the north-east it is often found on gneiss, so that its occurrence in one locality in a limited way on the Talchirs only is the more remarkable. It seems to be chiefly, if not entirely, confined to the lower levels, and I never found a trace of it on the higher hills, though in such positions it is commonly met with in Sirguja.

There is nowhere, so far as I know, a greater thickness of it than about sixty feet. In the eastern part of the field it forms wide spreads, which completely conceal the underlying rocks. In lithological characters this laterite resembles the laterite of Midnapore and elsewhere.

VI.—FAULTS AND DYKES.

The character of the south-western boundary having been described in the previous pages, little remains to be said, and recapitulation is, perhaps, unnecessary. Although no single section can be pointed to as absolutely establishing the faulted nature of this boundary, still the general tendency of the observations which have been made is to point in that direction, while the difference in the character and age of the beds which are successively brought into conjunction, and the remarkable straightness of the boundary, are strongly corroborative of the same view.

With this exception there is no evidence of any faulting throughout the area, and most of the boundaries have been distinctly seen to be natural.

Dykes.—But one case of trap also has been met with in the field; this is at Kirarama in the Barákar area, where a dyke is exposed for a few yards. A similar rock is seen at Kondaimunda, in the gneiss, and the two may be continuous. It must be noted that there is a possibility of this being only the peak of a trap-like metamorphic rock which strikes up through the Barákars. Its lithological characters quite favor this possibility.

VII.—ECONOMIC RESOURCES.

The economic resources of this field are—Building materials, Coal and Iron.

BUILDING MATERIALS.—As in other coal-fields containing Damuda rocks, many varieties of sandstones occur which would be applicable to building purposes. Hitherto the only

* NOTE.—The cave is in a friable bed of slightly ferruginous sandstone, which I noticed was perforated in a peculiar manner. On examination each of these perforations, at least those which looked freshest, contained the nest, or rather den, of a small spider, while the older ones contained exuviæ of spiders.

It was perfectly obvious that these perforations, which were mostly ¾ of an inch deep, had been made by the spiders by gradually removing the friable rock grain by grain.

rocks which have been used in this way are the Talchir sandstones of Sasun. These furnish a suitable material for copings and similar purposes in Sambalpur. Recently they have been employed in the manufacture of washing vats for lac works. The building stone which is chiefly used in Sambalpur is a schistose quartzite which is found in the station. Limestone of limited amount, but good quality, occurs in the Talchir rocks to the south of Luponga (*vide* p. 105). Kankar is found in most of the alluvial tracts, but is not generally abundant. The Vindhyan rocks south of Padampur on the Mahanadi include an excellent limestone, which is the source of lime chiefly resorted to in the district.

COAL.—The seams which are exposed in the portion of the field at present under description are neither very numerous nor individually of promising quality; but it must be remembered that the coal-measure rocks are not only, as a whole, very slightly disturbed from their original horizontal position, but are much covered by superficial deposits, and that there is a complete want of sections which might show the succession of beds constituting the group. The true, or even approximate, value of the field, therefore, can only be ascertained by borings. In the meantime it may safely be asserted that there is a fair prospect of this field proving to be of considerable value.

Of those seams which are at present exposed I should recommend that at Dibdorah as being the one which is most likely to reward exploitation. The advantages which this seam possesses are the following:—The coal is of fair quality, much better probably than might be supposed from the assay, the sample having been taken from under water; the thickness is at least six and a half feet. The seam being at the surface, and having only a small dip, might be worked by simple undercut quarries.

Lastly, the locality is the nearest to the Mahanadi, being only about six miles distant from that means of carriage. The chief difficulty in working this seam, indeed the only one that I know of, will be caused by water which it may possibly be found not very easy to dispose of, especially during the rains. This, of course, would only be felt while the works were carried on on a small scale; with extended operations suitable provision could no doubt be made, but the narrowness of the valley in which the seam is situated must always cause some trouble.

With this in view it would obviously be best to break ground first (provided, of course, that the seam is first proved to extend so far) at the watershed between Dibdorah and Jogidhipa; this would involve somewhat longer carriage, but would secure an outlet on either side for the ejected water. The water would almost entirely be from surface sources, as the red clays which occur with the upper sandstones would, I think, prevent excessive percolation from the water-bearing rocks of the highlands.

The sections given above of the other seams in this part of the field (Ebe valley area) do not indicate any coal of workable thickness. According to the assays and my rough examination in the field, No. 9 of the Durlipali is the best coal, but of it there is only one foot. No. 4 of the same section is two feet six inches thick, but the quality is very inferior. It must be remembered, however, that the whole of this seam, as well as that of most of the others, is not exposed. As regards carriage, the Durlipali seam is much less favourably situated than that at Dibdorah; the distance from Sambalpur as the crow flies is twenty-five miles. During the rains, however, the Ebe river, which is only six miles distant, might be used as a means of carriage. The Lukanpur seam, regarding which little is known at present, is situated in an enclosed valley difficult of access, the road to which from the Mahanadi would probably be from ten to twelve miles. The Dulunga seam is about sixteen miles from the Ebe. Of the large seams in the Baisunder I have spoken in my previous report; the coal from them might, perhaps, to a small extent, be brought down that river to the Ebe also during the rains.

Some of the seams in the Kelú valley may very possibly contain good coal, but they are difficult of access, being thirty-six miles, as the crow flies, from the Mahanadi. Carts, if they could get over the ground at all, would have to travel probably not less than sixty miles. To Sambalpur the distance by any possible route would not fall far short of 100 miles.

Still more unfavorably situated as regards roads are the seams in northern Hingir to the west. The Kurket river there, however, would afford a means of transport during the rains. I saw a large boat being built at Rabo on the Kurket, so that navigation is so far possible; indeed, the river bed, thence to its junction with the Mahanadi, contains no serious obstructions of any kind.

So little is yet known of the coal of the Talchir field, that it would be impossible at present to institute a fair comparison* between the two. Unless the coal of our field is of better quality it could not compete successfully in Cuttack owing to the much greater distance it would have to travel. At the same time the Mahanadi is closer to the eastern end of the Ráigarh and Hingir field than it is to any part of the Talchir field, and the Brahmini, owing to obstructions, is not much better as a means of transport than the Ebe or Kurket would be.

The prospects of the ultimate development of this coal-field depend altogether on the future extension of a line of railway into that part of the country. If the project for connecting Calcutta with Nagpúr, by a direct line, be ever carried out, this field will attain considerable importance, should the borings, which must first be made, prove the existence of abundant and good coal, and of their doing so, there is, I think, a fair prospect.

ASSAYS OF COALS†.

	Moisture.	Carbon.	Volatile.	Ash.
Durlipali No. 4 of Sec. ...	5 3	26 4	36·5	37·1
Durlipali No. 9 of „ ...	11·8	50·2	36·8	13·
Lakanpur	9·2	33·4	34·4	32·2
Dibdorah	9·9	39·9	33·6	26·5
Dulunga	11·	45·2	33·6	21·2
Mograpali	11·2	46·1	40·	13·9

IRON.—Within the Barákar group there are, as has been indicated on a previous page, two and possibly three zones of ironstones. Assays have not been yet made, but some of the ores appear to be good. As to quantities, so far as superficial examination goes, I think at Kodaloi and some of the other localities on that horizon there is a large supply which could be easily worked. Of the abundance of ore in the hills at Rampur, east of the Ebe, I have already expressed my doubts, but on these points it is impossible, without some preliminary clearing of the ground, to speak with certainty.

The zone of ironstones which runs with the south-west boundary, at the top of the Barákars, seemed to be thin and poor.

In the upper sandstone series ironstones also occur, but are seldom used by the native *Lohars*. In several instances I found that the Lohars of villages which, owing to wood being abundant, were situated within the upper sandstone area, procured their ore from the Barákars some miles distant. Except towards the frontiers of the Hingir highlands, there are few *Lohars'* villages in that zemindari, but in no part of the country which I have visited are they so abundant as in Rampur. At many of the large villages there are furnaces, but the greater

* Selected coal from the Talchir field has been found to answer fairly well in small steamers on the Cuttack canals. The cost, owing to expensive carriage, was, however, too high.

† By Mr. Tween.

number are worked by colonies of Lohars who form temporary villages where timber is abundant, passing to new localities when they have exhausted the supply in their vicinity. Although Sâl (*Shorea robusta*) is the wood most commonly used for making charcoal, I found the Bijasal (*Dipterocarpus marsupium*) seemed to be preferred by some. Bamboo, though abundant, never seems to be used. The wood is cut into logs about 3½ feet long, or rather more, and is burnt in holes which are about 4 feet square and 18 inches deep. Small branches are not used. The furnaces are somewhat smaller than the largest which are used in Bengal; they are furnished with a tray above, in which a quantity of mixed ore and charcoal is kept, which can be raked into the top of the furnace by the person working the bellows without other assistance. This, of course, is a great saving of labour as compared with the usual system which involves the presence of a second person to feed the furnace. Differing from the practice in Hazaribagh, the same individuals make the *giri* (bloom) and also work it up into iron for the market. The *giris* were much smaller than in Hazaribagh, in one case at Jodiboga not exceeding 6 or 7 seers, generally, perhaps, they are about 10 seers. So far as I could make out, the Mahajans get from 15 to 20 seers of iron for a rupee from the Lohars, but owing to the advance system and the transactions being chiefly in kind, this cannot be accurately ascertained.

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22nd October 1875.

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OF THE

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OF

INDIA.

VOL VIII.

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THOMAS OLDHAM, LL.D., F.R.S.,

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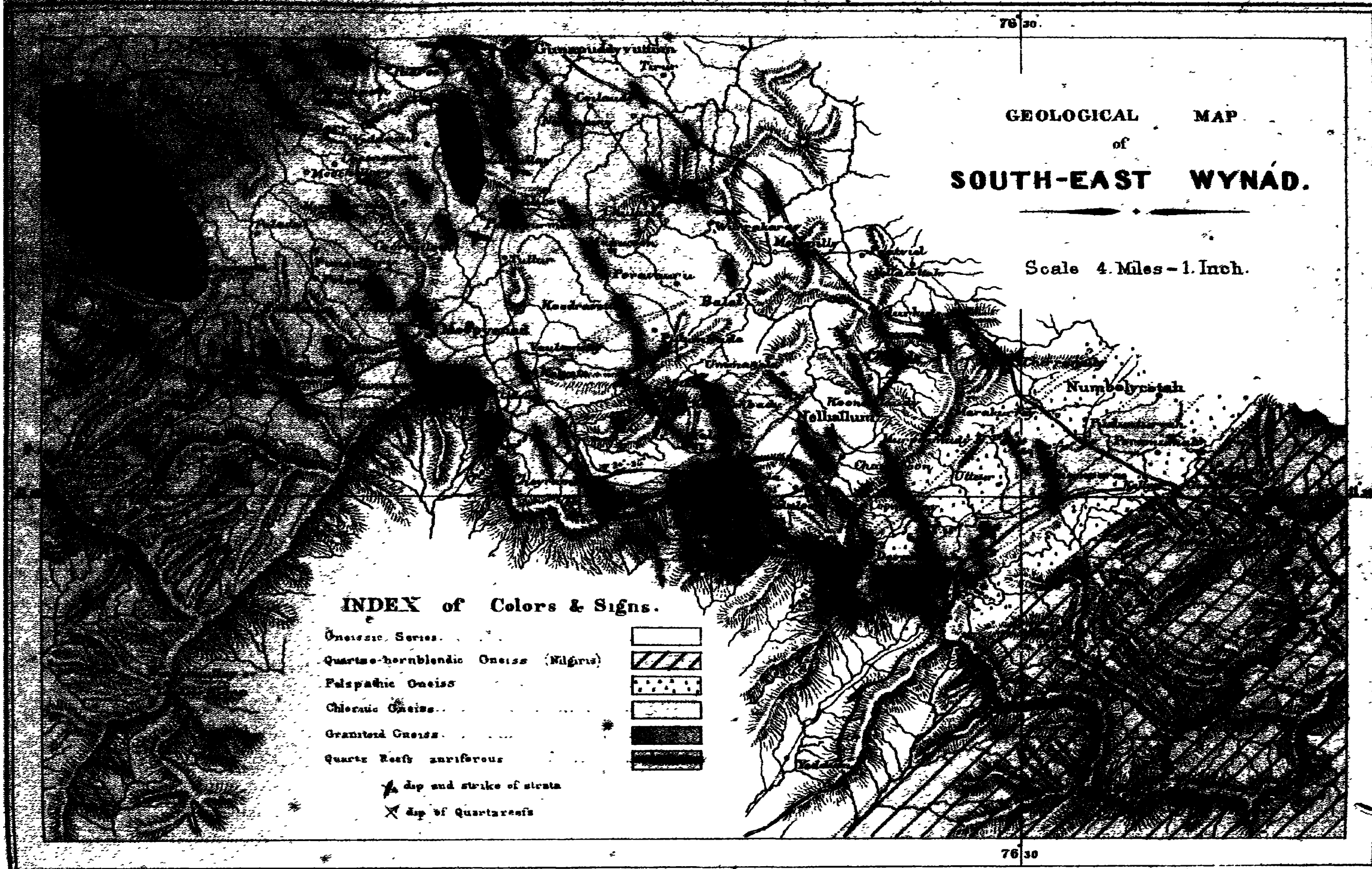
CONTENTS.


76 30
GEOLOGICAL MAP
of
SOUTH-EAST WYNÁD.
Scale 4 Miles – 1 Inch.
Numbolycotah
Yelhallum
Ultour
INDEX of Colors & Signs.
Gneissic Series
Quartzo-hornblendic Gneiss (Nilgiris)
Felspathic Gneiss
Chloritic Gneiss
Granitoid Gneiss
Quartz Reefs auriferous
dip and strike of strata
dip of Quartzreefs
76 30

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1875. [May.

Preliminary note on the Gold-fields of South-east Wynád, *Madras Presidency, by* William King, B. A., *Deputy Superintendent, Geological Survey of India, Madras.*

Reason for present brief report.

The attention of the Madras Government having been again called, after a lapse of nearly forty-two years, to the occurrence of gold in the Malabar District, it was considered advisable that an examination of the country should be made by the Geological Survey of India. It now, however, turns out that the area over which the auriferous deposits and quartz reefs extend is so large, that a considerable period of time must elapse before a full report of the whole district can be made. In the meanwhile, as a gold mining company had been started with the intention of opening up the quartz reefs known to exist in Wynád, and more particularly those near Dayvállah, my attention was first directed to this region. The country examined up to this time constitutes a local division of this part of the district and is sufficiently large and important in itself to be described separately in these Records.

Topography of Wynád plateau.

The intermediate elevated terrace of mountain-land lying between the low country of Malabar, the loftier plateau of the Nilgiri mountains, and the Mysore territory, called the Wynád, has been conveniently separated (principally by the Coffee Planters) into three divisions: North Wynád, South Wynád, and South-east Wynád; and these larger areas are again parcelled out after a native classification into *Amshams.* South-east Wynád includes among others the Nambalicode, Moonád, and Moopia-nád Amshams, the latter being the most north-westerly of the three, and touching on South Wynád or that in which the central village of Vythery is situated. Manantoddy, the principal town of the plateau, is in North Wynád.

The present paper has to do with so much of South-east Wynád as lies to the south-south-west of and alongside the road from Gúdalúr to Sultan's Battery (Gunnapuddy-vuttom of Atlas-sheet). The other boundaries are the Nilgiri plateau and Ouchterlony valley on the east-south-east; the great line of precipices of the Western Ghâts from Nádgáni (Carcoor ghât) to the mountain of Vellaramulla on the south-south-west, and a high water-shed running from Vellaramulla to Sultan's Battery on the north-north-west.

Elevation.

This mountain terrace has an elevation on an average of [illegible] 3,000 feet; but out of it rise peaked ridges and hills of considerably greater heights, varying from 3,500 to nearly 7,000 feet a

Forest covering, cultivation.

Along the edge of the ghâts, occasionally for short disatnces inside of these, and down the great ribs and intermediate trenches to the low country, all the ground is covered by dense and lofty black forest. Inland, there are rounded grassy hills enclosing valleys, interspersed with good belts of forest, most of which is, however, of poorer tree jungle than that of the ghâts. Nearly all the valleys contain swampy flats, which are largely cultivated as paddy or rice-fields. The coffee gardens, which are the European speciality of Wynad, have, as a general rule, been made in clearings near the edge of the ghâts in the black forest, or in the denser parts of the inland jungle.

Climate

A good deal of misconception appears to exist as to the healthiness of Wynád. As far as my own personal experience goes, the climate from the end of September to the middle of January is tolerably well adapted for Europeans. I am informed by the planters that it is even healthier from May to September; so that there are only three months in the year when the country is not healthy. Many planters leave during these months for the coast, or the Nilgiris; but others are known to have remained with their wives and children for two and three years continuously.

On the other hand, the climate is not suitable to the natives, except such as belong to the country, as the Chetties, Mopahs, Korumbars, Pannirs, &c.; but much of this unsuitability, may, however, be due to carelessness of the men brought into the country, and the fact of their being away from their homes.

Next to the tremendous rains of this region and the two or three unhealthy months, the land-wind is perhaps one of the worst evils to be encountered. Bungalows are built so as to present a sheltering side to it; it is dangerous to sleep in; and it is about as disagreeable to be felt or heard as the bleakest east wind in England. Fortunately, it seldom lasts all day except for a short time in the year; and in its place comes the oppositely mild and soothing wind from the western sea.

History of the gold question.

The Malabar District has been famous for gold from time immemorial. Gold is still washed for in the low country and in Wynád; and it used to be got in old days from quartz 'leaders' in the hill country around Dayvállah, Nellialum, &c. Two tribes of people obtain the gold. The *Pannirs* wash for it in the alluvium, surface soils, and river sands. The *Korumbars* dug down to and excavated the quartz leaders. Tradition says that large finds of gold have been made at odd times by the Korumbars. The Pannirs rarely find more than four annas' worth of gold in a day each man. The latter only wash for gold now (in the Wynád) in the off season, when they cannot get work in the coffee gardens at five annas a day.

In 1793 the gold mines of Malabar appear to have been noticed by the then Governor of Bombay, who tried to get information on the subject; and they were farmed by the Madras Government in 1803.

In 1831 Mr. W. Sheffield, Principal Collector of Malabar, wrote an interesting report on these gold mines, upon which Lieutenant Woodly Nicholson, 49th Regiment, Madras Native Infantry, was deputed to explore the country with a view to the development of this industry. The latter officer visited the Nambalicode Amsham, examined all the old workings of the Korumbars on the Chulaymullay near Dayvállah, and obtained gold from the surface washings in the same neighbourhood. He also visited all the known gold localities in the low country of Malabar. He does not seem to have thought much of Dayvállah, and the gold obtained was not so pure as that from the plains. His acquaintance with the practical business of the matter and his knowledge of the geological structure of the country were

very poor; but his perseverance at the work was marvellous under the difficulties, real and imaginary, with which he had to contend. A committee was then appointed, consisting of Mr. F. Clementson, Principal Collector, Major A. Ross, Superintending Engineer, Malabar and Canara, and Dr. F. W. Ward; and an able report, dated 25th May, 1833, was the result. These three gentlemen practically condemned the working for gold, as an European industry, in the low country of Malabar. My own examination of the plains has as yet only been a cursory one; but without going so far as this decision, I am inclined to agree to a great extent with it, more especially as it would appear from what we now know that there is sufficient evidence to show that European energy is more likely to meet with success in the Wynád.

In 1865 or 1866 Mr. Stern (of Australian experience) paid a prospecting visit to Wynád and made trial of the alluvial deposits, of which there are several in the form of flat swampy land along the courses of the streams. He tried near Dayvállah by sinking pits to 'bottom rock' and always got gold, but not in sufficient quantity to make it worth while continuing his work.

Within the last year or so attention was again called to the occurrence of gold in the Wynád. Some of the planters had lived in Australia previous to their coffee experiences, and being more or less acquainted with quartz and its occasional associated minerals, they were naturally struck with the quartz in Wynád, while they also knew that gold was, and is, obtained by the natives. There was, however, a want of capital, and no one had seen gold in the quartz until Mr. Withers, the present Manager of the Alpha Company, came down to Wynád. Mr. Withers, who knows how to wash for gold, and is acquainted with quartz reefing, prospected the country for a long time until he felt convinced that nothing was to be done at alluvial and surface washing. He then explored the old pits and workings of the Korumbars and finally settled on a quartz reef in which he found gold visible. This reef and the ground alongside had been extensively worked in old times by the Korumbars. In one of the numerous caves he found the remains of one of these native miners, and thus the lode came to be called the "Skull Reef."

The Alpha Gold Company was then started, the prospectus of which states on the authority of "the Company's Manager and two of the Directors, who have had much experience of quartz-reef mining in Australia," that the stone will yield about one ounce of gold to the ton of quartz.

Alluvial sources of gold, not rich.

The most common mode of occurrence of gold in South-east Wynád is naturally in the Recent deposits, such as the surface soil on the hill-sides, the stream sands and gravels, or the true alluvial flats (Vayals or Veils) which are so frequent a feature in this upland as to have given it the name of the "land of swamps"; but in none of these ways does it seem that any large quantity of gold is stored up, except perhaps in the swamps which have as yet only been tried by Mr. Stern, when they were found to be as poor as the rest of the land.

From surface soils.

The surface soils are generally very thin, and they are not extensive enough to justify any large attempt at washing by hydraulic sluicing. Still they are perhaps the favorite resort of the Pannirs who can always from known patches of ground produce a certain small amount of gold. On four occasions these men worked for me at places around Dayvalláh, but they never got as much gold as would pay for their employment at five annas a day for each man. Occasionally, however, they chance on richer finds. The largest known fragment of gold found within the last few years in Wynád weighs over seven pennyweights, but it contains some quartz. It is of pale color, and is not much rolled; in fact it has evidently not been washed far from the present reef,

and has thus not been subjected to that exposure and attrition which seem necessary for the production of the finally purer metal usually obtained from alluvial washings. In addition to this, a further small rolled fragment of good yellow gold without quartz, weighing nearly 11 grains, was lately found by the Pannirs of Dayvallâh; and a larger one, weighing 21·9 grains, is in the possession of Mr. H. V. Ryan of Glenrock—Mr. Minchin and Mr. Ryan have each occasionally employed coolies on their estates to wash for gold, but they do not find that the quantity obtained is sufficient to encourage any further exploration. The latter gentleman has collected 8·1 dwts. of gold, amongst which is the small nugget just mentioned. Out of this, 150·9 grains had to be collected by amalgamation and there were 21·6 grains of dust. The gold generally found by the Pannirs is in very fine dust, or in small flat spangles only collectible from the black iron-sand, finally left with them, by amalgamation in the wooden washing dish or *murriya;* but at times there are somewhat larger pepitas. This size of the grains agrees with what I have seen of the precious metal in the matrix.

From stream sands, &c.

The stream sands are next resorted to, but they are of no extent in this part of Wynád, as there are no large reaches, or hollows in the river beds in which gold could be stored up, while, as I shall presently endeavour to show, there is not much likelihood of its being retained in them, even if it were washed down in any quantity. As it is, the usual small amount of gold is obtained here also by the washers. In both conditions of deposit, as surface soil, or as river sand, the men nearly always only scrape a few inches of stuff from the surface; they do not dig down to bottom-rock, or to any bottom-layer of compact stuff answering to pipe-clay.

Poverty of these accounted for.

It will thus be seen that a somewhat different mode of occurrence of the gold dust (not in pockets, or at the bottom of lighter and permeable materials), and system of washing adopted (surface scrapings only being sifted) exist in Wynád from what is known in Australia and California. Much of this may be attributable to the heavy denuding force of the south-west monsoon; or, in other words, a very large proportion of the ore weathered out of the quartz veins and adjacent country rock is carried down during the rains to the low country of Malabar. At such times every stream in Wynád is a rushing torrent in which no sediment is allowed to rest until it reaches the slower-flowing, wider and deeper, rivers of the plains. As the monsoon slackens, a little new auriferous soil is allowed to remain on the cleaned hill sides, and the old basins and reaches of the stream beds are again filled up with their usual accumulation of mud, sand, and gravel, and thus a small supply of gold is collected. There is no doubt that in the decreasing flow of water, gold dust and heavy iron sand must necessarily at many places settle down first in the hollows, but these are few and far between, irrespective of their being difficult of access by the natives. At any rate such places are not known or searched to any extent in Wynád; and it seems to me that the fact of the men preferring generally to wash stuff scraped from the surface of the coarsest gravel and sand banks (the very places where the drifting gold would be retarded by the rough bottom and then permitted to settle down among the stones) points directly to the transporting power of the monsoon streams. This is also borne out by the habit which the men have of going at certain intervals to places known to them as having yielded gold on previous occasions, where they do not find the accumulations of centuries of denudation, but the gatherings up of only one or two seasons.

Proper alluvial deposits.

In certain parts of Wynád, and more particularly around Sultan's Battery, or in the neighbourhood of Manantoddy, the valleys are filled in with extensive and thick alluvial deposits through which the streams almost immediately after they leave the steeper hill-sides, often pursue a long and devious course, or become lost for a time in deep and dangerous swamps. In Nambalycode and Moonád

these alluvial flats are not so frequent, and they are small in extent. There are no traces anywhere of their having been searched for gold, except in so far as the patches of surface soil alongside the streams, or on the edges of the flats, where auriferous soil could gather, may have been searched by the Pannirs.

There can hardly be a doubt but that gold in some quantity must lie in these deposits, for when they were being laid down, even if the present rainfall existed, it is quite evident that the flow of water was sufficiently retarded, possibly by lakes which then occupied the places of the present flats, to allow of a great thickness of separate patches of the denuded material of Wynád being retained. It is, however, very questionable whether the amount would be sufficient to repay the washing of such places, for they are throughout the year charged with water for the greater part of their depth, and they are largely made up of very unstable materials. The cost of excavation, puddling, and pumping engines necessary to keep large works free of water would be enormous. In addition to this, it is probable that work could only be carried on in the dry season, three months of which are unhealthy for both Europeans and outside natives, particularly in these low-lying grounds.

Difficult to be worked.

The places where gold washing has been carried on in the area under description are frequent in the Nambalycode and Moonád Amshams; but there is now no tradition of such work ever having been carried on outside of these, although in Mr. Sheffield's Report of 1831 mention is made of places, such as Choolyode, purporting to be in the neighbourhood of Sultan's Battery, where indeed there are Pannirs, though these men are not skilled in the use of the washing dish. This apparently unsearched condition of the northern part of the field, and the ignorance of the Pannirs as to the use of the *murriya* would seem to indicate that there should be no expectation of finding any gold dust in that part of the country were there not the view that there was possibly always sufficient occupation for these men in the well cultivated lands of these northern Amshams, while in the Nambalycode country, &c., they were driven by the land-owners to search for gold, the land not being so well adapted for agricultural work.

No traces of gold washing in northern Amshams.

The next source of Wynád gold is the matrix or the quartz veins, and to a slight extent the rocks traversed by these; and here again the natives of Malabar have been beforehand in mining operations though only in a very small way when the enormous extent of veinstone is taken into account. These Korumbars have worked the smaller and more easily broken up veins often to a depth of 60 or 70 feet. The western slopes of many of the hills in the three *Amshams* already enumerated are burrowed like rabbit warrens with pits, often only four or five feet apart, and communicating by short galleries. Chulaymullay, one of the conspicuous headlands of the Western Ghâts near Dayvallâh, was once extensively mined in this way. Lieutenant Nicholson thus describes what he saw in April 1831: "After cutting our way for several hours in the thickest part of the jungle on the mountains, we came upon the mine in question, consisting of three shafts about five feet each in diameter, and ten from each other, forming an equilateral triangle, the deepest of them extending to about seventy feet, since a stone dropped in took four and a half seconds to reach the bottom. We soon found that this mine was not the only one, for, having penetrated as far as we possibly could through the jungle towards the summit of the mountain, we discovered no less than twenty-seven shafts all sunk in the same manner and forming a chain of triangles as before described, the disposition of which with regard to each other led me to suppose that they have all subterraneous counter-shafts communicating with each other, and probably extending to a large main shaft which I trust may be discovered on the arrival of the pioneers." The same style of work is to be

The conditions of gold in the matrix.

seen near Nádgáni Bungalow and westwards, towards Chulaymullay, near Nulliallum, and away on to Cheyrumbadi. In these places these men seem to have led water to the steeper hill slopes and got at the numerous small veins on the foot-walls of the larger reefs by regularly sluicing down the hill-side even to the extent of causing occasional landslips. In the Glenrock Estate the upper part of the great valley or *churrum* in which it is situated is all of fallen earth, and there are still evidences of large sluicings having been carried on, while the face of the ridge north of Hudiabettah is pierced all over with pits as in Chulaymullay.

Wynád generally a country of quartz reefs

According to every information that is to be obtained, the whole of Wynád appears to be traversed by quartz reefs, some of which appear in the low country of Malabar, while others are traceable into the Ouchterlony valley; and even, it is said, on to the spurs of the Koondah mountains to the south. At present it is only known certainly that they are very strong and numerous in South-east Wynád.

Auriferous reefs.

In the Nambalycode Amsham there are at least eighteen reefs, nine of which are auriferous; and the immediate neighbourhood of all has been worked by the Korumbars, or washed by the Pannirs, for gold. Most of these eighteen reefs are traceable northwards into the Moonád Amsham.

Still further westward, by Pandalur, Cheyrumbádi, and Cholády to Vellaramulla, there are at least twenty-four more reefs, those in the neighbourhood of Pandalur having had their 'foot-walls' and 'leaders' very extensively worked in old times by the Korumbars. Those of Cheyrumbádi and Cholády have not yet been sufficiently examined; but it may be here stated that one of the richest gold-washing regions (Kathaparaye) of the low country could only have been supplied with its gold from the Cholády and Vellaramulla drainage basins.

Appearance of gold from reefs and washings.

The gold obtained from the reefs is of a pale color; that from the leaders and washings is generally yellow; and that from the surface washings nearly always of a good yellow color. The natives know this difference, preferring the 'mud gold' to the 'stone gold,' which last they designate also as 'white gold.'

Fragments of stone gold are found at times by the Pannirs in their washings of surface soil; but there is nothing known of pale gold dust having ever been got in the washings.

Quality of alluvial gold.

In an assay made of some of the gold obtained by Lieutenant Nicholson in 1831, the following result is given:—

DAYVALLAH.

Gold ...	90·88
Silver ...	8·86
Copper ...	·26
	100·00

This was evidently gold obtained by the washers; for Nicholson does not seem to have

Two samples from auriferous surface soil near Dayvalláh have been assayed by my colleague Mr. Tween, one of which, as will be seen, is very near Nicholson's specimen, while the second is richer.

			Carats.	C. grains.
No. 1, Gold	93·00	=	22	1 Fineness.
Silver	7·00	=		
No. 2, Gold	90·00	=	21	2¼ Fineness.
Silver	8·67	=		

Neither of these three assays comes up to the quality of the dust obtained by Nicholson in 1831 from the Malabar low country, which varied from 94·53 to 99·22 in the percentage of pure gold.

When the matrix gold is analysed a very different result is obtained showing a considerable falling off in the fineness of the ore. There is also a much greater disparity between it and the alluvial gold than is usually displayed between the two kinds in Australia, or even in California; though the percentage of pure gold in the Wynád ore is nearly the same as in that of the latter country.

Mr. Tween has supplied me with the following assays :—

1. Skull Reef		2. Monarch Reef.		3. Mixed sample.	
Gold	67·07	Gold	82·69	Gold	86 86
Silver	32 93	Silver	11·32	Silver	10·96

cording to the scale of fineness make the ore of—

	Carats.	C. grains.	
Skull Reef	15	3	Fine.
Monarch Reef	19	2⅝	"
Mixed sample	20	2⅜	"

An ounce troy of the mixed sample, taking the mint price of standard gold at £3-17-10½, would be worth £3-13-6¼, or about Rs. 36-12-2.

The sample from the Skull Reef is remarkably poor, and if it be a fair average (which I do not think it is, as I have seen gold at times in the richest part of the lode having a much better color than that of the amalgamated sample tried), it would reduce any calculation as to the return of this reef by nearly one-third. The specimen from the Monarch Reef is only from one crushing of four pounds of stone; and cannot be considered as so fair a sample of gold right across the lode which was the case with that taken from the Skull. The mixed sample is from amalgamated ore taken from six reefs; and it may be taken as an average for Wynád gold as far as it has been yet tried. It is very probable that the fineness of the gold in the different reefs will vary just as frequently as it is known to do in other auriferous countries.

Mode of occurrence of gold.

As is usual in most gold regions, the precious metal occurs here in the reefs or large lodes, in the leaders and spurs; and in the 'casing' or nondescript rock lining or casing these.

In leaders and small veins.

The ore of the leaders and casing is mostly visible, and is what is technically called 'coarse gold;' that is, it occurs as small segregations in the interstices of the quartz, or of the assembled cubical crystals of what is now limonite, or even in the interior of these cubes. It is also very often visible in the unaltered iron-pyrites which is not quite so frequently seen in the leaders as its pseudomorph limonite. A very common mineral in the casing of some of the leaders is pyrolusite, in which also the gold is often visible. The blue-black variety of pyrolusite occurs also with the gold visible at times.

It is this variety of gold which the Korumbars evidently always sought for, principally from its splendid color; then, because it is so easily seen and often obtained without the trouble of amalgamation; and lastly, because it occurs in the casing and leaders or small veins of quartz, all of which were easily broken up in the extemporized mortar holes which are still to be seen cut in adjacent blocks of gneiss or quartz, or calcined prior to pounding. The old miners seem never to have broken up the big reefs, though they 'cayoted' or dug in among the 'riders' or masses of country rock and casing enclosed or contained in the interior of the reefs.

In the reef.

The gold of the reefs or great lodes is generally 'fine gold,' or such as is disseminated through the gangue in extremely fine particles quite invisible even with the magnifier. After the quartz is crushed and washed, this fine gold may be seen on the furrows of the rude wooden dish used by the Pannirs, like little painted waves of color. At times, however, the gold is visible even in the white quartz in short streaks and little angular masses; though it is more generally seen in the same form in the red and brown stained ferruginous and cellular quartz.

Appearance of reefs.

The quartz reefs are, without exception, white colored on the outcrop or when they come to 'grass'; so that it is utterly impossible to say from a surface inspection whether they shall be richly auriferous, or not. The Skull Reef of the Alpha Company which has as yet shown most gold is as white on the surface as any other of the reefs.

All the reefs are badly defined at the outcrop: they just show a few feet over the ground and never stand up as marked walls cutting across country as some quartz reefs do in other parts of this Presidency. Occasionally, they show well on the eastern slopes of the grassy hills, as when their upper surfaces or 'backs' just happen to form parts of these slopes.

Lie of reefs.

In such an undulating, or deeply denuded, country as the Wynád, it is difficult for an ordinary observer at first sight to make out the true direction of the great quartz-lodes, their dip or underlie being rather low; but when followed out for long distances they are seen to have a prevailing north-north-west, south-south-east strike or 'run' across the country. At places there may be a slight deviation from this; and for short distances there are slight curves; but, on the whole, this is the direction for South-east Wynád, and it is always across, not with, the stratification of the rock of the country. The dip is always to the eastward, generally at an angle of 25° to 30°. There is, however, a tendency in the 'underlie' to be lower on the tops of some of the hills, and to increase in the valleys. For example, the Skull Reef at the present place of quarrying dips at 20° to 25° east-south-east, while on the top of a hill a short distance to the north, some 200 feet higher, it is 10° and nearly flat. The same feature shows in the Hamsluck Reef; and the Monarch Reef, at its lowest level, has a much higher dip than on the hills.

Of the leaders.

The leaders and spurs, or side veins, strike off to the westward from the foot-walls, or undersides, of the big lodes. They dip and wave about in all directions, very often rather to the northward.

Extent of reefs.

The great ledges or reefs of quartz appear to vary much in thickness both in their length and depth, sometimes dying out, or at least becoming very thin for short distances in their length; and, as I am inclined to [illegible] behaving thus in their depth. Some of the reefs are traceable with occasional [illegible] or thinnings-out for great distances. The Monarch Reef would seem to be traceable for about nine miles; other reefs show their outcrops at intervals for two, four, or six miles.

It is much more difficult to say anything as to their depth in the underlie. Very many show by their outcrop on the hills and valleys that they are 300 or 400 feet in depth. The Hudia-betta Reef, on the edge of the ghâts, gives indications of being 1,300 yards down its underlie; while there is slight evidence that some of the reefs west of this show down in the low country. On the other hand, two large reefs, as they run south of the Nádgáni-Gúdalúr road, are not seen in the deep trenches, and it is difficult to say whether they are covered up or have actually thinned out.

The thickest actual section is 15 feet in the quarries of the Skull Reef, though there must be greater thicknesses than this close by. A good average thickness in most of the reefs may be taken as from 4 to 9 feet. The thickness of the leaders naturally varies very much. They appear to run generally up to 2 feet or so; but there is one under the Dunbar Reef which is 6 to 8 feet in thickness.

A very common feature in the outcrop of the big 'ledges' is, that they show strong on the higher parts of the ridges and hillocks traversed by them, and thinner or not at all in the saddles. This at first sight points to a probable thinning out in depth; but there is the view that the higher ground is more open to denudation while the saddles would to some extent be covered up by débris of the country rock, and their slopes are not so steep as those of the ridges; the outcrops, too, are deceptive, for they are often encumbered with big lumps, of fallen quartz. Indeed, the masses of fallen quartz are in some places so large and so tumbled together down the western slopes of the grassy hills that they give the appearance of stone *in situ*.

Rock of the country.
Gneiss.

The rock of the Wynád, or as it would be termed in mining regions the 'country rock,' is gneiss, belonging to the oldest known series in India, termed variously the *Crystalline*, *Gneissic*, or the *Metamorphic series*; and is of very variable constitution in different parts of the country. Ordinarily, there is a massive foliated quartzo-felspathic, or quartzo-hornblendic variety, with intercalations of micaceous and talcose schists; but all these are, except in the hill ridges, generally weathered or decomposed into a more or less tough clayey rock, granular and friable with the undecomposed quartz, dark red and brown from the hornblendic and chloritic constituents, or white, pale colored, and cheesy, or soapy from the felspathic, micaceous, and talcose ingredients of the original rock. There is a large quantity of ferruginous matter distributed through the gneiss in the form of minute granules or crystals of magnetic iron; and in one particular band in the Marpanmúdi ridge, as laminæ of gray hæmatite. Hence the red and brown colors of much of the decomposed rock; and also its occasional lateritoid character: while at every working of the surface soils or the river sands by the Pannirs there is the unfailing accompaniment of black iron sand.

The strike of the foliation, or indeed of the lamination and the bedding of the gneiss, is usually east-north-east, west-south-west, the dip being mostly at high angles to the southward; except in the Vellaramulla and Sultan's Battery country, when a west-north-west, east-south-east foliation is prevalent with some folding, and even reduplication of the beds.

Several bands of gneiss.

In South-east Wynád four belts of gneiss are recognizable. Along and south of the Nádgáni-Gúdalúr high road there is the northern edge of the highly syenitoid and quartzose gneiss of the Ouchterlony valley and the Nilgiris. North of this and striking about east-north-east, west-south-west, is a highly felspathic band with two minor belts of chloritic gneiss. In this, the Dayvállah zone, there is very little true massive rock until—still going north—the conspicuous and picturesque serrated and lofty ridge of Marpanmúdi and the Needle Rock is reached. Here

a very hard and thick band of highly quartzose and ferruginous gneiss is met with, in which the run of the strata is rather tortuous; while there are indications of a synclinal roll in the great wall of rock crowning the ridge above old Dayvállah and in the Needle Rock. In the depression north of the Marpanmúdi range there is a wide belt of much more varied gneisses, which, on the whole, are not so felspathic as the Dayvállah band, nor so quartzose and hornblendic as that of the Ouchterlony valley. This zone is traversable to beyond the Cheyrumbádi hill station, when a further curved belt of gneiss with more schistose bands comes in as in the Vythery Cholády and Sultan's Battery country.

Two 'cores' of granitic rock.

In the country just mentioned there are two large hill masses of granitic rock; namely Yeddakulmullay near Sultan's Battery and Mumramulla or Culpetta hill nearer to Vythery. These are, as it were, great rocky cores around and over which the foliated gneisses were laid down, the great arches or undulations of which are now evidenced by the westerly dip and subsequent synclinal displayed in the Chambra, Yellambalari, and Panora peaks and the rest of the Vellaramulla range, the easterly dip of strata on the Sultan's Battery and Manantoddy side of the country; and the narrow strip of folded beds in the wall like crests of the Marpanmudi ridge near Dayvalla, south of which there is the generally southern dip of the Ouchterlony valley strata. The rock of Culpetta hill is a very rough weathering, pale flesh-colored, rather coarsely crystallized compound of quartz, felspar, and silvery mica, showing no trace of foliation. It wears away into huge rounded masses of still harder rock, giving the hill rather a resemblance to those of the Mysore country in which the gneiss is often highly granitoid. Yeddakulmullay is made up of a much finer textured rock of quartz and felspar, and minute particles of black and greenish mica, which when weathered looks very like a coarse buff sandstone. On the western flanks of the mass, the rock is rather laminated or foliated. With both these cores of granite there is a decrease in the number and thickness of the quartz veins; but these appear again quite strongly to the northwards crossing the Sultan's Battery—Culpetta road.

Hardly any intrusive rocks in South-east Wynád.

Otherwise, the country is remarkable for the non-occurrence of any strictly intrusive rocks except in a very small way. There is a dyke of hard, compact dark-green diorite seen for a very short distance in the Hamsluck estate to the west of Dayvállah. The width of this dyke is about 35 feet; and it is striking east by north, west by south, nearly vertical. It cuts off the northern end of Hamsluck Reef. A few small largely crystallized granite veins occur here and there over the Dayvállah band of felspathic gneiss, as near the dyke just mentioned and around Gúdalúr. Large flakes of mica from these are common on the Nádgáni-Gúdalúr road.

Quartz reefs become granitic.

In connexion with this rare occurrence of granite veins it may be noticed that the quartz reefs of Cheyrumbadi are in some cases charged with assemblages of large plates of mica of 2 to 3 inches in diameter; and there thus seems to be a tendency in the western veins to become granitic rather than simple quartz lodes. Likewise from Cheyrumbadi the quartz of the reefs is becoming rather granular and saccharoid.

Variation in country rock does not affect reefs or their contents much.

Sufficient data have not yet been gathered to be able to write with any confidence as to how the quartz reefs may have been affected by the different belts of gneiss in which they were deposited. The ledges certainly seem to show stronger in the Dayvállah belt. They nip out very thin, and even disappear in the hard Marpanmúdi range; but they come to grass again to the north of this. There are perhaps not so many reefs to the north of the Marpanmúdi range as to the south of it. The occurrence of gold in the leaders does not seem to have been affected one way or other on either side of this ridge, for the old Korumbar works are as frequent about Nellialum and Pandalur as on the Dayvállah side.

The quartz reefs which have been traced out, or are sufficiently marked, are as follows commencing from the Gúdalúr side of the country, where and eastward of which there do not appear to be any ledges, auriferous or otherwise, for some miles at least :—

Enumeration of quartz reefs.

Name of Reef.	Character.	Average proportion of gold.	Lowest proportions		Highest proportion.
1. Eastern	Worked on foot-wall ...	....	...	...	...
2. Paliampara ...	Ditto .	......	.	...	...
3. Bear	......	.....		...	...
4. Nádgáni	Worked on foot-wall ...	......	...	...	...
5. Monarch ...	Auriferous .	... ..	½ dwt....	2 dwt....	69. 19 dwt.
6. Hamlin	Worked on foot-wall ...	.....	...	...	...
7 Un-named	Ditto ...	......	...	...	...
8. Korumbar	Auriferous	4 dwt. to ton	½ dwt...	7½ dwt....	180 dwt.
9. Un-named	Worked on foot-wall	......	.	..	...
10. Cavern	Auriferous ..	......	.	...	.
11. Skull	Ditto	11 dwt. to ton	2 dwt.	25 dwt....	..
12. Hamsluck .	Ditto	3 dwt. to ton	1 dwt.	7 dwt....	..
13. Hamsluck, middle	Ditto ...	10 dwt. to ton	8 dwt....	12 dwt....	.
14. Hamslado Waterfall .	Ditto .	11 dwt. to ton	3 dwt....	19 dwt.	60 dwt.
15. Balcarras	Ditto	3 dwt. to ton	½ dwt.	...	
16. Puntaloor ...	Worked on foot-wall ...	. ...	..	.	...
17. Hudiabettah .. .	Auriferous ...	...	.	...	.
18. Glenrock	Worked on foot-wall ...	......	...	.	

By 'auriferous on the foot wall,' it is to be understood that the foot-wall of the reef and the side veins therefrom have been dug at by the Korumbars, and that they are reported by the natives to have given gold. In these cases, I think tradition may be believed to a large extent.

The *Monarch Reef* is, as stated above, traceable for about nine miles from the western side of the bridge below the Nádgáni Bungalow, across the Dayvállah road (about a quarter of a mile east of the toll bar), up the long grassy ridge to the summit of a lofty cross-ridge overlooking old Dayvállah; and on to the wide gap in the Marpanmúdi range, down through the Dingley Dell Estate, and on past Koontalaudy towards the Gúdalúr—Sultan's Battery road. At its southern end a drive was put through this reef, where it was found to be 4 feet thick; but I am inclined to think that this is only part of the reef, a 'rider' or large enclosed piece of the country rock having been met with. The varied results given in the table from this reef are accounted for in this way: At first, color of gold was got in the samples taken from the drive sufficient to warrant the expectation of about 2 dwts. of gold to the ton of quartz. Subsequently, a fragment of stone from the surface, weighing 3 lbs., was crushed and 2·3 grains of gold obtained, which is in the proportion of 69·19 pennyweights to the ton. Stone, in fragments of which gold was clearly visible, was then taken from the same place and 350 lbs. of it subjected to rough crushing in a stamper belonging to Mr. J. W. Minchin, and passed over a large blanket cradle, but the outturn was extremely disappointing, as only about 3 grains of gold were got, and yet more than this had been seen before the stone was pounded up. It was soon found, however, from subsequent experiments, that the gold

Details of auriferous reefs.

must have been lost in the stamping box which was merely a planked structure round the stamp-head, and as no more trials could then be made on this reef, an average result has not been entered in the table.

The quartz of the Monarch Reef is generally a milky-white coarse-textured rather glassy-lustred compact rock. At times it is stained brown or red along the fractures, and shows thin sheets and seams of brown iron rust. Flakes of bright golden colored mica are frequent; and there are rare seams of greenish talc and chlorite. White iron-pyrites occurs at rare intervals. The quartz is rudely laminated with the lie of the reef, and spurs of talcose schist are frequently running into the body of the lode. The casing is partly of talcose schist, with frequent laminæ of pyrolusite. This description applies to so much as is exposed in the drive or cross-cut.

The foot wall and leaders of this great reef have been extensively worked on the slope of the ridge overlooking the old Dayvállah valley in Mr. Hughes' clearing, and in the valley itself.

Korumbar Reef and others.—Between the Hamlin and Skull Reef, there are at least five lodes, but they are only traceable at intervals to the district road. One, called after the native miners who pointed it out, gave another set of curious returns, which will illustrate the faulty condition of the extemporized crushing apparatus with which work had to be done.

Seven pounds of stone from the Korumbar Reef were hand-pounded and gave 12·40 grains of good yellow gold; and a further crushing of the tailings of white iron-pyrites, of which there was a large quantity, added ·40 grains to this; being in the proportion of 8 oz. 10 dwt. 16 grains to the ton. One hundred and sixty pounds of this stone were then pounded, and all but 10 lbs crushed and passed over the cradle, when gold at the rate of half a pennyweight to the ton was got. But from the 10 lbs. remaining which was hand-crushed there was gold at the rate of $7\frac{1}{2}$ dwts. to the ton In the meantime, another sample of 4 lbs. of stone was brought in from a new reef (Hamslade Waterfall) which gave 7 grains of gold, I then went to this reef with the men and quarried out about 70 lbs. of stone which was divided for separate trial by wet crushing and by hand work, when the following outturn appeared —

30 lbs. hand work	...	..	.	6 3 grains of gold.
40 lbs. wet crushing	.	...	..	1·3 „ of „

The latter sample showed more gold than this in the uncrushed stone. Even if the wet-crushed result be true, the proportion for this reef is 10·19 pennyweights. It was evident, however, that gold had been lost in the stamping box; had indeed possibly never left it, for the bed plate (fixed) could not be completely boxed in.

The outcrops of these reefs are very short for any continuous distance, but there can be little doubt that they will be found continuing northwards nearly up to the Marpanmúdi ridge; and some of them show down in the Nádgáni estate in the Carcoor *cherrum*. They are thin, about 3 to 4 feet on the edge of the *cherrum*, and look at other points as though they kept to this. Their appearance is very favorable, being more or less colored with oxide of iron, laminated, and full of white iron-pyrites; and they show gold at times; in fact, they are just as promising-looking except in the matter of size as the reef to be noticed next.

The Skull Reef.—The outcrop of this lode is traceable nearly continuously for about seven furlongs, but it is in all probability connected with other outcrops of quartz to a complete length of at least four miles. Only a small part of the southern end of this reef has been taken up by the Alpha Company. At the southern end it commences on the edge of the Western Ghâts, a little more than a mile and a half due west of the Nádgáni Bungalow, on the rounded grassy knolls of this part of the Dayvállah country. Thence it runs up to the top of a high hill overlooking Dayvállah and down to the road a short distance east of the bazar. Strong leaders from its foot-wall cross the road nearer the village and run

through the wooded hillock on which the old fort is situated. Its next appearance is in a high ridge on which the Roman Catholic Chapel is built, and again in the Harewood and Kintail Estate east of Mr. Hamlin's bungalow. Beyond the cross range of Marpanmúdi, it again shows in the bottom of the Strathern Estate: and still further northward in the Nallialum country.

The direction of the vein is, as usual with these south-east Wynád lodes, *viz.*, north-north-west, south-south-east, with a dip or underlie varying from 10° to 25° east-south-east. On the top of the hill overlooking Dayvállah the angle is low, in fact becoming flat, but it increases as the reef descends, being at the quarries about 20° to 25°. At the place of quarrying there is a large irregular surface of the vein exposed on the eastern slope of a grassy spur of the hills. This is full of caverns excavated by the old native miners who evidently scraped and dug at every bit of casing, enclosed country rock, and the leaders. The Manager of the Alpha Company is at present quarrying in at this exposed surface, and preparing stone in readiness for the crushing machinery which is to arrive in a few months from Australia. At the quarry the reef is about 15 feet thick, of rudely laminated quartz; laminations with the dip and strike. The back or upper surface of the lode is of coarse white quartz. From this, as was seen by a cross-cut through the reef, the rock becomes more and more ferruginous and stained of dark brown, black, and reddish colors, cellular or mouse-eaten, and charged at times with white iron pyrites much of which is decomposed, sulphate of iron and even traces of sulphur being left behind. At about 12 feet the quartz is more highly colored, very ferruginous, very cavernous, and gold is often visible in minute strings and masses. The quantity of rock worked out has not been sufficient to show whether there is any definite 'gold streak' in this lode.

Through the kindness of the Directors of this Company and their Manager, Mr. Withers, I have been supplied with a fair set of specimens from this cross-cut, which have been crushed, washed, and amalgamated in a rough manner. Very good color of gold was got in nearly every dish of pounded stone; but the results from amalgamation were very poor at first. The enormous quantity of iron pyrites associated with the gold came in the way of amalgamation, causing the mercury to granulate and become coated with the iron, sulphide; in fact 'flouing' (Australian term) set in.

I have not been able, owing to the difficulties in the way of crushing, failure of some experiments, and a want of time, to obtain a complete series of specimens and results from one cross-cut in this reef, much less from different parts of the lode, which would, of course, be the fairest way of testing the quartz, but such as have been got are now given—

Specimen of quartz.	Weight.	Appearance, color, &c.	Results.	Depth in cross-cut from 'back' of reef.
1	20 lbs	Compact, coarse texture, laminated; white color ...	2 dwts. to ton	1st foot.
2	28 lbs.	Still white in color, but stained with ferruginous matter	2·5 dwts. to ton	3rd foot.
3	.	Whitish, more discolored with iron	None.	5th foot.
4	30 lbs.	Ditto ditto ditto	Good color in dish; lost in amalgamation.	7th foot.
5	18 lbs.	Still white, but ferruginous	5·18 dwts. to ton	10th foot.
6	18 lbs.	Highly colored, red and brown, ferruginous, cellular, with white iron pyrites. Gold visible... ...	[illegible] dwts. to ton	12th foot.
7	18 lbs.	Ditto ditto ditto washed and amalgamated in my presence by Mr. Withers. Gold not visible	[illegible] dwts. to ton	13th foot.

For this cross-cut there is therefore an average result of 11 dwts. to the ton. At this point the richest part of the reef is a band of the laminated quartz about two feet thick within a couple of feet of the footwall or underside of the reef. The average of this rich band is 22·68 dwts.

Mr. Withers informs us that he has got almost as good results out of a shaft and cross tunnel which he made at the southern end of the outcrop, but that the reef is there narrower, about 9 feet in thickness.

Hamsluck Reef.—About half a mile west of the high hill-outcrop of the Alpha Company's Reef overlooking Dayvállah village there is another strong lode cropping up in Mr. J. W. Minchin's estate of Hamsluck. The lowest part of this reef, or what is seen in the bottom of the valley at its foot, is about three furlongs in length; and from this as base the reef slopes up the eastern side of a hill about 300 feet high. The strike of the reef is about the same as in others: the dip being about 20° to the eastward, though it is at a much lower angle on the summit of the hill. The known thickness of this reef is from 4 to 8 feet. The lode is cut off to the north by the dyke of green stone already noticed. It is traceable southwards into the Chullaymullay mountain, and probably runs under the northern end of Perseverance Estate. The eastern slope of the Chullaymullay alongside the latter estate has been perfectly riddled by the pits and excavations of the old miners who evidently worked at the side veins on the underside of the lode. Small samples of quartz were crushed, and gold was always got showing clear in every dishful of stuff; but the result was small owing most probably to the presence of a great quantity of iron sulphide. Subsequent crushings gave the proportions shewn in the table.

Dunbar and Balcarras Reefs.—About two miles further west, but on the northern side of the deep trench leading to the low country by Carambat, there is a good outcrop of a reef about 4 feet thick in the Dunbar Estate. Mr. Powell, the Superintendent of this garden, when down showing me the reef, was successful in knocking out pieces of quartz in which small streaks of gold were visible. The underside of this lode is very like in color and contents to that of the Alpha Company, the richer seam in the quartz being on this side. Leaders are numerous and large. The casing is of talcose schist, and seamed with ferruginous and manganese streaks.

The lode is traceable northwards into the Balcarras Estate, where there is a great show of white quartz on the eastern slope of one of the low hills. This part of the reef has been very extensively riddled by the old miners. In fact, all its extension northwards towards Pandalúr has been washed, and its immediate neighbourhood on the underside is still a favorite locality for washing during the rainy season. It runs through the Elizabeth and Sandhurst Estates, and close alongside the Caroline and Mr. Holmes' application, and thence northwards.

Prospects of Wynád up to date.

My observations so far appear to show that quartz-crushing should be a success, in the Nambaly-code Amsham at any rate. Here, there are eighteen reefs which are more or less auriferous in themselves, or as to their leaders. The leaders and underside of these are all known, or reported, to be auriferous with coarse gold; and it is probable that the great reason they are not worked now is that the pits necessary to be dug by the Korumbars would be too deep for their style of work, water being the great obstacle likely to be met with. The big reefs were not worked by these men on account of the difficulty of breaking up the stone, and because the gold is distributed too finely through it to have paid hand labor. With machinery and modern appliances, the reefs should pay even if only 3 dwts. of gold are got always from the ton of quartz.

The average proportion of gold for fifteen trials on different reefs is at the rate of seven pennyweights to the ton; and it is almost certain, that many of these would have given a better outturn, could more perfect crushing apparatus have been used at the time.

The fineness or touch of the ore is inferior to that of Australia, but it compares favorably with Californian reef gold. The percentage of 86·86 is given above as a fair average, for on looking at the differences between alluvial and matrix gold in other regions, it is found that they agree very closely with the difference between this sample and the alluvial ore of the upland; while the assays of the Skull reef, and the upland and low country washings do not exhibit any gradation consistent with the amount of exposure to which the two alluvial golds must have been subjected.

In Australia these ratios are as follows:—

	c.	c.g.	Percentage of pure gold.
Alluvial gold	23	$1\frac{4}{8}$	... ... 97·500
Matrix gold	22	$0\frac{7}{8}$	... ... 92·875
Difference ...	1	$0\frac{5}{8}$	... ... 4·625

Californian tables give about the same difference, but the fineness of the gold is much lower, *viz.*, 21 c. 0 cg. or 88·00.

The Wynád experiments give—

		c.g	Percentage of pure gold.
Alluvial	21	$3\frac{7}{8}$	... ... 91·95
Matrix	20	$2\frac{6}{8}$	... ... 86·86
Difference ...	1	$1\frac{1}{8}$	... ... 5·09

This close approach of differences for the three countries implies also that a richer gold than this is not to be expected from the reefs; though it must not be forgotten, as already stated, that the ore from the small veins and leaders is evidently superior.

The reefs are easily got at, the gneiss traversed by them being often wonderfully decomposed almost to any reasonable depth. For a long time there may be no necessity for deep sinking, as a large quantity of stone is held in the many rounded hills so common over the country, and thus little trouble is to be anticipated in getting rid of water in the mines when drives can always be made at low levels. The very prevalent idea that the gangue must necessarily be richer the deeper it is searched, will doubtless be brought to bear on any mining which may be carried out; but the safer plan in a preliminary opening up of a country like this will be to work at what will pay, rather than venture to mine ground requiring expensive pumping apparatus, in which there is—after all that has been written on the subject—no absolute knowledge that there must be more gold. It is worthy of notice that the present surface of Wynad has probably only been exposed after a slow wearing away of over 2,000 feet of superincumbent gneiss which was once continuous between the Nilgiri mountains and the Vellaramulla range, in which also these quartz veins may have been continued in their upward hade to the westward; and supposing that reefs become richer in depth, then the richness now got of 7 pennyweights, by denudation of 2,000 feet, is not any great increase on whatever may have been the state of things at the then higher outcrop; while, if the same ratio of increase is to be counted on, any further considerable increment of gold can only be expected at a greater depth than is likely to be reached on the plateau. A reasonable view is that the occurrence of rich streaks of gold will be exceedingly variable; while the prevalence of very fine gold dust in Malabar indi-

cates that finé gold is perhaps most evenly distributed through the matrix, and therefore that beyond the first fifty feet, to which depth weathering may be supposed to extend, the return shall be tolerably constant.

The working of the mines may possibly not be as cheaply done as the present rate of wages in Wynád would lead one to expect. The coolies employed on the coffee estates get from 4 to 5 annas a day per man; but there is a decided scarcity of labor, and thus a higher rate must follow if the quartz reefs are to be worked. A further addition will be in the employment of a small number of skilled European or Australian workmen in the handling of machinery, and in directing the getting out of the largest quantity of stone, and timbering up. Still, with these additions, the labor in Wynád may be expected to be always cheaper than in other gold countries.

Great facilities towards the crushing of the stone are presented in the way of water-power, which might in some cases be obtained direct from perennial streams with sufficient fall for any ordinary wheel; or it might in most other instances be led or stored up without much difficulty or expense. The stampers, &c., of the Alpha Mining Company are to be driven by steam; but there would have been no difficulty in applying water-power at the site of their works.

Having then the presumable average proportion of gold in the stone, the value of the gold obtained so far, and the quality of the labor to be employed in getting it out, an estimate can be made of the possible paying capabilities of the Wynád reefs from the statistics of the cost of extracting gold in Australia, where the labor is manifestly much more costly than it can be in Wynád.

In Mr. Brough Smyth's "Gold Fields and Mineral Districts of Victoria" the following returns are given of the cost of complete extraction of the ore from a ton of stone:—

	£	*s.*	*d.*
Ballaarat District	0	8	8½
Clunes	1	0	3
Bright	0	4	4
Wood's Point	0	11	6
Sandhurst	0	11	8
Maryborough	1	9	8
Castlemaine	0	11	5½
Maldon	2	1	8½

Some of these rates are very high and paid on stone got from a good depth in places ill-situated as to supplies of wood and water, so that the average of 17*s.* 4¾*d.* is far beyond any expected estimate of this kind in Wynád.

The value of Wynád reef gold, when compared with the mint standard of £3 17*s.* 10½*d.* is about Rs. 36-12-2 per ounce, troy, which is, of course, somewhat lower than the mercantile rate. Seven pennyweights, or the outturn of 1 ton of stone, would then be worth Rs. 12-13-10, which would leave a balance of Rs. 4-2-8 on every ton crushed, even if the high Australian rate were ever attained.

The country must now be tried cautiously, while better or worse results may in the meanwhile be obtained from experiments which are being carried out, even before the arrival of the machinery of the pioneer Company now waiting to venture in the field. There is no promise like that of the Australian or American gold-fields; no great nuggets have been found; the washings have always been poor, though there is a small supply of gold swept down the hill sides every year from the wear and tear of the quartz ledges, and the areas over which they can be applied are very small; and the gold which has been seen in the

reefs is only in minute strings and grains. The ground can only be worked out by capital, the most perfect machinery, and skilled hands to guide the cheaper labor of the country in getting out the stone in the safest and readiest manner. And naturally, where the percentage of gold in the quartz is as yet so small, everything will depend on getting out a sufficient tonnage of stone in a given time.

Until more is known of the gold-producing powers of the Wynád, no better guidance can be given than the following by Mr. A. R. C. Selwyn, Director General, Geological Survey of Canada:* "It should not be forgotten that the most favorable indications are not always reliable, and the sanguine prognostications they so frequently give rise to are not borne out by the result of actual working; wherefore I should, even under the most favorable circumstances, not advise any one to invest in such enterprises to an amount beyond what he can afford to lose without serious embarrassment."

Land tenure in Wynád.

Hitherto the land in Wynád has been principally parcelled out in coffee gardens, either free-hold, or paying an annual rent to the Rajahs who hold a great quantity of the ground, or direct to Government. At the same time, after a certain period, a revenue is derived from all the gardens by the Government, whether it be Rajah's land, or not. Now that gold mining is likely to become an industry, a new set of land interests are being developed. The Rajahs, of course, retain their right to all minerals and can sell these as they like. The Government of Madras has not yet, I believe, decided as to how they are to act in the matter, except that applications for land for gold-mining and for agricultural purposes on which quartz reefs are supposed to exist, are being reserved for consideration until the question of mining interest is settled.

In the meantime the Rajah of Nellambor has (according to their prospectus) leased a block of 15 acres of land near Dayvállah to the projectors of the Alpha Gold Company for twelve years at an annual rent of Rs. 225. Since then it is reported that the Rajah in recent applications demands 10 per cent. on the out-turn of any gold-mining which may be carried on; and it is very probable he may change this rate. Nearly all the land in the Nambalycode Amsham is owned by the Rajah of Nellambor. Equally, as with the revenue derived from estates on Rajah's lands, it may be found advisable that the gold from these reefs should pay a royalty to Government.

In conclusion, I have to tender my thanks to all the planters whom I have yet met in Wynád for their great kindness and hospitality, and for their assistance in every way. Also for the readiness displayed by the Directors and the Manager of the Alpha Gold Company in allowing me to examine their quarry and giving me such specimens as were required. To Mr. J. W. Minchin of Dayvállah the greatest debt is due for having allowed all the specimens to be crushed at his extemporized stamper and subsequently manipulated by his Pannirs and Korumbars.

* Notes and Observations on the Gold Fields of Quebec and Nova Scotia

GEOLOGICAL NOTES ON THE KHAREEAN HILLS IN THE UPPER PUNJAB, *by* A. B. WYNNE, F.G.S., *Geological Survey of India.*

The Khareean* hills are perhaps better known, to the natives of the country at least, by the name of Pubbí, which seems to have an application to their low but broken forms. They are situated in the Upper Punjab, seven or eight miles southward of the river Jhilam, and station of the same name, forming the southern of the three minor chains which link, as it were, but without absolute continuity, the salt range to the Western Himalayan mountains.

These Pubbí hills extend from near the battle-field of Chílíanwala, and closer to the banks of the Jhilam, in an east-north-easterly direction for about twenty-eight miles in the direction of Bhimber (in Kashmere territory), but sink into a sandy nallah about four miles short of that town. They form throughout a low rugged chain, cut into by numerous ravines, having a general width of three or four miles, and a summit elevation of some 4 to 500 feet above the plains of the Jhilam and the more extensive ones of the Goojrát district.

Their culminating point is towards the western end of the range, and their declination eastwards is very gradual. In the latter direction they are crossed by the grand trunk road from Calcutta to Peshawur and by the Northern State Railway in progress of construction.

The aspect of the hills is monotonously arid, barren and rugged, presenting everywhere steep or precipitous descents into dry sandy nullahs. Towards the eastward, the 'Pubbís' are further apart, and scattered cultivated patches occur between the hills, which are separated by that peculiar labyrinth of ravines known in this country and the Pot'war as '*khuddera*.'†

The hills are composed of an enormous accumulation of sandstones, sands, conglomerates and clays belonging to the upper part of the tertiary rocks of the Northern Punjab.

From their position it was thought probable that here the Sivalik sub-division of these rocks might be developed, and their relations to the underlying beds discovered if the same marked unconformity, as occurs in other places, existed. On examination no trace of unconformity within these hills has been found, and though the soft and friable nature of most of the strata would answer well enough for the description of Sivalik rocks in other regions, their whole character suggests their identity with the uppermost deposits of the Pot'war to the north, similar clays and sandstones there having been always found to pass regularly downwards into the lower and older portion of the series, so far as has been gathered from observations hitherto made.

The arrangement of the Pubbí rocks is simple; they form a distinct anticlinal, the axis of which coincides with the higher parts of the range, a downward inclination of this at either end bringing at least a portion of the beds round to form the opposite sides of the hills. With the general form described there are many undulations of the rocks in bold

* The word is pronounced by the natives Kharee-in, and the famous battle-field of Chílíanwala they speak of as Che Íunmojeeani.

† As characteristics of these Pubbí hills it may be mentioned that the chief obstacles to pedestrian progress, besides the innumerable khuds and ravines, are the difficulty of obtaining foothold on steeply sloping clay surfaces covered with small pebbles, sandstone fragments or nodules of kunkur which slide under the feet, the insecure nature of vertically weathered parts of the soft sandstones and clays, and the trying strain in the dry sandy beds of nalahs.

A striking feature of the ground is the contrast between its dryness and the abundant evidence of abrasion by water.

Although now so dry and barren, these hills were once populous and even thickly inhabited, as is evident from the very numerous large village ruins scattered over them, and the size of some of the graveyards belonging to these villages,—fast yielding to the atmospheric erosion which frequently exposes the graves, showing that the potsherds left by the inhabitants were more lasting than their bones.

Other relics of a perhaps still older period are brick blocks of large size, though the buildings formed of these have all but disappeared.

confluent curves; they sometimes assume horizontal positions, sometimes dip steeply into the plains, but never present any high opposing dips to the general anticlinal conformation. The highest point of longitudinal curvature of the axis upwards coincides with the summit of the hills at Koat Great Trigonometrical Station, east-south-east of the village of that name and some eight miles westward of the trunk road. From this point the beds both slope to the ends of the range and curve downwards upon its sides. Here, therefore, in the bottom of the ravines the oldest rocks of the exposure ought to occur.

These are drab-brown and slightly pink or purplish red clays alternating with zones of coarse friable gray or greenish speckled sandstone formed of comminuted waste of granitic or crystalline rocks, grains of quartz, felspar, hornblende (or such a mineral) and spangles of mica. Layers and runs or scattered pebbles of hard crystalline rocks are not uncommon, increasing in quantity as the section ascends, with a predominance of white quartzite fragments well worn, until on the flanks of the hills these pebbles of larger size and in greater numbers, including a few of hill-nummulitic limestones in many places thickly sheet the ground, pointing to the local destruction of loose conglomeratic pebble beds, which, from their friable nature, are seldom found *in situ*. The various and repeatedly alternating zones of clays and sandstones are often thick, ranging from 6 to 30 feet or upwards. In eastern parts of the range the clays are more developed, deep khuds often showing little else than zones of thick purple clay, each band purple below and of a bright ferruginous yellow above, while the intercalated sandstone bands are by no means prominent, save where they form caps to the hills or hard ledges defining the outlines of the ground in a widely extended and multitudinous series of scarped out-crops.

Through the whole of the sandstones, but rarely (if ever) in the clays, teeth and fragments of large bones are thinly scattered. The beds may be searched for long distances without finding anything more than an obscure fragment broken before becoming embedded, yet in the debris between sandstone out-crops the fragments are more numerous, though seldom sufficiently perfect to be worth removal. These fragments have not been found in the clays, yet some dark liver-coloured bones seem to have come from the purple portions of these. Fossil wood has not been met with. The bones are usually whitish or buff, the teeth too hard to be touched by a knife, the bones often softer and calcareous, while some huge tusks are replaced chiefly by a pinkish white soft marly looking brittle clay or earth.

The state of fossilization exactly resembles that of the Lehrí bones thought by Mr. Theobald to be of Nahun age (see Records, Geological Survey, No. 3, 1874).

The remains found in the above described beds include parts of large bones, such as the humerus, scapula, jaws, teeth and tusks of huge pachyderms. One of the former had a girth of 2 feet 7 inches, and fragments of a pair of tusks measured 12 feet in the aggregate with a girth of 2 feet in places. Large molar teeth resembling those of ruminants also occur, with some smaller teeth; portions of joints of less sizeable, leg bones, vertebræ, fragments of large deciduous, deer horns nearly as thick at the attachment as a man's wrist, many mammalian rib bones, numerous unrecognisable fragments, and one small piece of the armature of a tortoise (?) none of which have as yet undergone comparison or determination.

From the general aspect of the rocks no hesitation would be felt in referring them to the upper portion of the Pot'war tertiary series, but it remains to be seen if the fossils will give any support to the idea that they may be newer, or that these and some upper beds of the Pot'war may both be Sivalik.

Perhaps the only feature which relieves the stratigraphical monotony of these beds is an indication of a slow transition upwards into strata even more incoherent and more recent looking than those of the mass of the hills. These upper and outer beds are coarse sandy

gravelly and conglomeratic layers with drab or yellow clays containing kunkur (as indeed do many of the clays lower in the series). These clays are of the same color, and present but little difference from the alluvium of the neighbouring plains, while the sandstones and gravelly beds or base of conglomerates are of a duller and more muddy aspect than the clean gray sandstones beneath. In the sandstone or gravelly parts of these rocks an occasional rolled bone fragment or broken tooth may be found, and in some of the conglomerates pebbles of the tertiary sandstones themselves occur; but notwithstanding the derivative aspect of the bones and of the last-mentioned pebbles, the containing rocks present no visible unconformity to the beds on which they rest. On the contrary, as stated, the transition to the softer and more recent looking layers appears to be gradual, while the dips are conformable and the newer beds are found all round the elongated oval formed by the hills.

Limits to these upper beds can only be approximately and arbitrarily assigned, but they may have a usual thickness of from 200 to over 400 feet.

The thickness of the whole Pubbí series must also be estimated with caution. For 18 or 20 miles from the eastern end of the exposure, a continuous succession of layers coming out from beneath each other may be traced, all lying at low but very perceptible inclinations which would, even at angles less than 5°, give a large total depth. When the cross-section, however, is considered, between 2,500 and 3,000 feet would seem a sufficient estimate for them all, and the probability is that the amount may exceed rather than fall within 3,000 feet.

Outside the inclined newer light colored layers the alluvium of the plains may be found horizontally abutting against and resting upon these rocks. It is of the common drab argillaceous or somewhat sandy, and occasionally kunkery or otherwise calcareous character, the only traces of fossils observed in it being small, white, dead Bulimus shells and part of the skull of some large bovine animal (perhaps a buffaloe) of recent appearance, but buried beneath from 8 to 10 or 15 feet of clay and exposed in the bank of a nullah. In neither case can these indications be taken as contemporaneous with the alluvium itself, for in so easily shifted and shifting a deposit, organisms of even more recent age might readily become enclosed. Much of the eastern part of the broken Pubbí country is formed of the deeply ravined alluvium.

It is to be hoped that the fossils collected, few, imperfect and fragmentary though they be, may afford sufficient evidence to relegate these Pubbí tertiary rocks to their proper place. Pending the examination of these fossils, the only conjecture that can be hazarded, based upon structural and petrological grounds, as well as Mr. Theobald's paper previously referred to, is that the fossiliferous portion of the Pubbí rocks is probably of Nahun age, while the age of the uppermost and more recent looking layers remains an open question.

CAMP, November 1874.

A. B. WYNNE, *Geological Survey.*

The following is a rough list of the fossils collected by Mr. Wynne during his examination of this small range of hills, drawn up by Mr. R. Lydekker, Geological Survey of India.

1.—*Equus sivalensis*, from north-west of Sundpúr.
- (*a*). 2nd premolar, right ramus of mandible.
- (*b*). Molar and parts of mandible.
- (*c*). First molar, Maxilla.

2.—*Equus sivalensis*, from near Changas, Pubbí hills—distal extremity, right metacarpus.

3.—*Bos*, Purr Kuss,* inside of stream, in bank 8 to 10 feet below surface,—part of maxilla of left side, containing 1, 2 and 3 premolars, and first molar.

4.—*Bos*, near Changas, Pubbi hills—

(*a*). 2nd molar, right ramus of mandible,

(*b*). Fragments of molars.

5.—*Bos*, near Changas, Pubbí hills,—3rd molar, left maxilla.

6.—*Bos*, north-west of Sundpúr or Sandepúra,—distal extremity, right metacarpus.

7.—*Bos*, from Gotriala to Besa,—fragmentary teeth, mandible.

8.—*Equus sivalensis*, from Gotriala to Besa,—1st molar, right ramus of mandible.

9.—*Bos*, from Gotriala to Besa,—external second phalange, left foot.

10.—*Equus*, Pir Jaffir, Pubbí,—left calcaneum.

11.—*Bos*, Pir Jaffir, Pubbí,—distal two-thirds, left calcaneum.

12.—*Bos*, Kniara, Pubbí,—neural arch and laminæ, thoracic vertebræ.

13.—*Bos*, Kniara, Pubbí,—proximal head of radius.

14.—*Cervus*, Pir Jaffir, Pubbí,—base of left horn.

15.—*Cervus*, Pir Jaffir, Pubbí,—base of right horn.

16.—*Cervus*, Pir Jaffir, Pubbí,—portion of horn.

17.—*Elephas hysudricus*, Pir Jaffir, Pubbí,—portion of molar.

18.—*Elephas insignis* (?) *Ganesa* (?), west of Pir Jaffir,—part of molar; stated to have been found with tusks two feet in circumference; from this probably belong to *Ganesa*.

19.—*Elephas*, Pir Jaffir, Mosque,—part of tusk.

20.—*Elephas*,—part of tusk belonging to No. 18.

21.—*Crocodilus*,—fragment of carapace.

Note.—As the fossils of *Bos* are only molar teeth and fragmentary bones, it is impossible to determine the species.—R. L.

REPORT ON WATER-BEARING STRATA OF THE SURAT DISTRICT, *by* W. T. BLANFORD, F.R.S., F.G.S., *Deputy Superintendent, Geological Survey of India.*

It appears to me, so far as I can form a judgment on the question from the correspondence forwarded to me, that the problem presented may be briefly stated thus: To determine how far the irregularity in the distribution of sweet and salt wells in the Surat district is due to the geological structure of the country, and to ascertain whether that structure renders it probable that sweet water will be found in those parts of the district in which none has hitherto been discovered.

In endeavouring to solve this problem, the first point for consideration is the geological structure of the district, and the second the knowledge which is available of the distribution of sweet and brackish water. On the latter head most of the information obtained is from local sources and not from my own observation, I am consequently not responsible for its accuracy, but any error I may make will doubtless be corrected by the local officers.

The geology of the Surat district is simple.* In the extreme east, about Mándvi and elsewhere, hills of basalt and other volcanic rocks are found. Upon these rest limestones, sandstones, gravels, &c., of tertiary age, the lowest of which abound in nummulites. These

* A sketch of it was given by Mr. A. B. Wynne, of the Geological Survey, in the Records, Geological Survey India, Vol. I, p. 27. I also described it in the Memoirs, Geological Survey, India, Vol. VI, p. 163.

rocks are seen in the Tapti river below Bhodhán and in the Kim river as far west as the neighbourhood of Eláo, but throughout most of the intervening area they are covered up and concealed by alluvial deposits, and they are nowhere exposed, except in one or two small isolated hills, throughout the country south of the river Tapti. By far the greater portion of the country consists of an alluvial plain, the surface being covered with a thick coating of black soil. Along the sea-coast are low hillocks of blown sand.

The alluvial deposits furnish nearly all the water obtained in wells, and these deposits demand therefore rather fuller notice. They consist of clays, sandy clays, and sand, much interspersed in places with concretionary nodules of carbonate of lime. Towards the surface they pass into black soil. They may contain beds of gravel (rolled pebbles) in places, but such appears to be uncommon, so far as my information extends. The different layers of sand and clay are probably very irregular in thickness and extent, but sections are rare, and very few borings have been taken. In those made for the Tapti bridge at Surat, however, as I am informed by the Executive Engineer in charge, a bed of hard clay with calcareous nodules, in which it is proposed to lay the foundations of the piers, was found to be very much thinner on one side of the river than on the other, the difference, which was not precisely determined, amounting to several feet. It is evident that this bed has an irregular and possibly a lenticular section, and the same is probably the case with all the strata in the alluvial deposits, whilst the more sandy layers in which, owing to their greater permeability, water is generally found, may very often thin out and disappear in the distance of a few yards.

I quite concur in Mr. Medlicott's remarks on the different reasons which may be assigned for the occurrence of brackish water in wells. These are, briefly, the presence of salt in the strata when originally formed, salt springs, and infiltration from spots in which salt is being deposited at the surface of the ground. To these may be added percolation from the sea or from estuaries, which, however, is practically identical with the third form. In the case of Surat, I believe that the salt was originally deposited in the alluvial strata.

The plains of Guzerat have every appearance of being estuarine or marine deposits formed from the clay and sand brought down by the Tapti, Narbadda, and other rivers. The deposits forming in the salt marshes and flats submerged at high tides near the mouth of the Tapti, which I had an opportunity of examining during my recent visit, are covered by a deposit differing so little from one form of the black soil, that it is impossible to draw a line separating the two, the blackish argillaceous dried mud of the estuarine flats and marshes being similar, both in colour and texture, to the black soil of the fields a few inches above the level of the highest tides, and this soil again differs but slightly, either in colour or texture, from the ordinary 'cotton soil' of Guzerat. Such differences as exist are, I think, due to surface action; to the effect of rain and chemical changes, impregnation with organic matter,* and agricultural processes, and I see no reason for doubting that the whole of the surface formations in Surat may have been deposited from salt and brackish water in tidal estuaries and salt marshes, precisely similar to those which are now being reclaimed and converted into arable land in places on the sea-board of the district. The more sandy beds must have been deposited where some current, due either to tidal or stream action, existed; the fine argillaceous black soil has probably been formed in back-waters and marshes.†

Evidence of recent rise in the land has been found in several places on the western coast of India; instances are known at Bombay, in Katthiawad, and in Sind. There is every reason

* It is probable that great part of Guzerat has been covered by forest, and the soil thus impregnated with decayed organic matter. In this manner the best and richest cotton soil has very probably been formed.

† My brother, Mr. H. F. Blanford, several years ago pointed out a similar mode of origin of black cotton soil on the Madras coast, and I found a similar deposit forming under the same circumstances in Orissa.

for believing that Surat has shared in this movement, and that the plains of south-eastern Guzerat have been raised above the sea-level at no very distant geological date.

Such being the geological nature and origin of the alluvial formations which cover the country, it may be inferred that more or less salt must originally have been left in the soil, and that the occurrence of saline impurities at present will depend upon whether they have been removed by the percolation of rain water—whether, in short, they have been washed out—since the deposits were formed. If other conditions remain similar, it is reasonable to anticipate that the salt would be removed more completely from those strata which have been raised to a greater height above the sea and from the more permeable beds, because the first, owing to their elevation, and the second, in consequence of their porosity, have been traversed to a greater extent by water seeking a lower level. It is also probable that elevation has been gradual, and, if this has been the case, it is evident that the surface deposits at a greater height above the sea have been first raised, and have consequently been longer subjected to the action of sweet water. But these more elevated portions of the plains are farther from the sea, and consequently it appears probable that the amount of salt in the alluvial deposits diminishes gradually in passing from the lower ground on the sea board to the higher inland plains, the presence or absence of saline impurities also depending on the more or less porous nature of the beds; or, which is the same thing, the proportion of sand and gravel to clay in their composition. Moreover, as the beds thin out within short distances, and the intercalation of sandy and gravelly layers with the less pervious argillaceous strata is variable, much irregularity in the extent to which the water is impregnated with salt may be anticipated. If the brackishness of the water depended directly on the permeability of the beds, we should expect that the wells yielding the largest supply of water would be the least impregnated with salt, and although this does not appear to be universally the case, some instances in its favor have come to my knowledge in the town of Surat, but the amount of salt in each instance is much complicated by peculiarities in the course taken by the water in reaching the well from the surface, and the beds it passes through during the process of percolation.

So far as I am aware, this theory of the mode in which the alluvial deposits of Guzerat have been formed, and of the distribution of beds containing brackish water, agrees with observed facts. With the important exception to which I shall presently refer, and which I can, I think, explain, of certain perfectly sweet wells close to the sea, the water found near the coast is more or less salt, whilst that obtained in the higher portions of the plains away from the sea is sweeter; but there is much irregularity. I have dwelt at some length on the theory by which I account for the brackishness of the well water, because it is upon the correctness of this theory that the conclusions formed depend; because, by explaining my views fully, I afford an opportunity to the civil officers and engineers of the district to test and confirm or refute them, and because, in one instance at least, I have found theories put forward which appear to me erroneous.

There are two circumstances at least which appear at first sight to be opposed to the views above expressed. One of these is the occurrence, already alluded to, of sweet water in wells close to the coast. I was only able to investigate one instance; this is at some bungalows between the villages of Dumas and Bhimpúr, just south of the mouth of the Tapti river, and about ten miles from Surat. At and around Surat city, on the road between Surat and Dumas, and in the village of Dumas itself, every well which I tried, and so far as I could learn, every well existing, is more or less brackish, some being sufficiently pure for use, whilst others contain water much too salt for either drinking purposes or irrigation. But at the bungalows just mentioned, which are within less than half a mile of the sea, the water in the wells is perfectly sweet. Now, the bungalows stand on hills of blown sand; the village about a mile away is on black soil. The wells at the bungalows are very shallow,

not more than 15 or 20 feet in depth; those at the village, which is, I think, on rather lower ground, are double that depth. It appears evident that the water in the bungalow wells is derived from the sand resting upon the comparatively impervious black soil, and that the water in the sand is sweet, because any salt originally contained in the porous sand has long since been washed out of it, as water can percolate it freely in descending to a lower level.

I am informed by Mr. Clarke, the Executive Engineer, that the case at Vaux's tomb, especially mentioned in Mr. Hope's letter, is precisely similar to Dumas, whilst at Bhugwa Dandee, where no good water could be found, there are no sand hills. If my explanation be correct, the sinking of deeper wells at the Dumas bungalows or at Vaux's tomb will probably result in brackish water being found in the beds underlying those which now supply the wells.

The other difficulty to which I have referred is the existence of numerous wells in various parts of the country, the water of which is said to have become gradually salter. This is rather opposed to the view above expressed, because it is probable that percolation removes the salt in any given stratum, and consequently wells should become sweeter by use if they undergo any change; that is, provided that the water always finds its way from the surface into the wells by the same route, and traverses the same beds in its course. But the removal of water from a well may occasionally produce an inflow from other strata than those from which the supply was originally derived, and thus salter water may be introduced. The question is a difficult one, and I think some further information on the subject of wells becoming salter is desirable. In the first place, I think the evidence of increasing saltness in wells should be rather carefully examined; of course no analyses of the water have been made, and, so far as I can learn, complaints about water becoming salt have been frequently made in order to obtain remissions of rent, as irrigated land is more highly taxed than land which is not irrigated. I should like to suggest the possibility that, in some cases at least, the change has not been in the water, but in the soil of the fields. As all the well water contains salts in solution, and as the water poured upon the land is evaporated, leaving the salts behind, a gradual concentration of the salt must take place in irrigated lands until it may, unless remedial measures be taken, become so saturated as to be unfit for cultivation, as in the case of the 'reh' lands of Upper India. In this case the blame would infallibly and justly be laid on the water used for irrigation, although no increase has really taken place in the saline impurities contained in the water.

I cannot say how far the wells in and around Surat represent those of the district generally, but if they do, I may add that the impurities of the water are not confined to common salt (sodium chloride). Some rough tests which I have applied with such means as were available, showed the presence of lime, alumina, and of an alkaline earth, which I believe to be magnesia, in considerable quantities.

If the views above expressed are correct, it is evidently improbable that better water will be obtained by deep boring, unless the strata at a depth below the surface are much more permeable than the superficial deposits; on the contrary, the deeper beds will have had less chance of being purified from salt by percolation than those near the surface. Where the beds at a greater depth are very porous, they may contain sweet water, but this is by no means certain, and I can see no reason for anticipating that the lower strata will prove very different in character from those exposed at the surface of the ground. Should rock be found, it is impossible to form an opinion without actual trial as to what the character of the associated water may be. The rock may very possibly belong to the lower tertiary strata, and similar beds in Kachh and Sind often yield brackish water.

Before concluding I may briefly advert to the water-supply of the town of Surat, to which my attention has been particularly drawn. I went over the town with Mr. Pandurang

Balkrishna, the Secretary to the Municipality, to whom I am indebted for most of the details mentioned.

Surat is a large town, with a population exceeding one hundred thousand. As in most old cities, the surface has been greatly raised in places by the accumulation of ruins of buildings and rubbish of all kinds. The town stands on the bank of the Tapti, here a tidal river, the water of which is sweet in the rainy season, but brackish at other times, and especially so in the hot weather.

There are in Surat numerous wells, one to nearly every house. The water of only two or three of these is used for drinking purposes; nearly the whole of the inhabitants obtain their drinking water from the river, from cisterns in which rain water is collected, or from wells outside the town. The depth of the wells inside the town varies from about 30 to about 70 feet, and the height at which the water stands in the wells above the datum to which all levels within the municipal limits are referred (100 feet below a fixed mark in the castle) varies in different wells from 50 to nearly 70 feet. As a general rule, the wells inside Surat city contain very brackish water; those outside the city proper, but within the old walls, vary in quality, a few being just drinkable, whilst outside the walls there are some wells of so called sweet water. This last, however, though far purer than that obtained from the wells inside the city, is decidedly more brackish than good drinking water should be, and on testing it, it was found to contain lime, magnesia, and other impurities in considerable quantity besides common salt. The same remark applies to those wells inside the city which contain drinkable water.

The latter are only two in number: one in the castle and close to the river bank, the other at the house of a Maharaj named Mandir. The former very probably derives its supply from percolation from the river when in flood,* another well not 100 yards away, but farther from the river, yielding brackish water. The well in Maharaj Mandir's house is rather deeper than usual, the bottom of the well being 48 feet, and the surface level of the water 56 above datum, and the supply is so large that an attempt to pump the well dry by a 6-horse power steam-engine scarcely produced any sensible diminution of the water level. At the same time other wells nearly of the same depth contain brackish water.

Two other incidents connected with the Surat wells may be here mentioned. The first is that there is a well in the public park used for watering the gardens: it is 63 feet deep, and contains, when full, 35 feet of water, the surface of the water being about 65 feet above datum. The supply is considerable, but the water can be pumped dry by a 8-horse power engine in 3 hours, and requires 24 hours to refill. After pumping for a short time the water improves, but when the well is left to refill it becomes brackish again. Another well, not 50 yards distant, contains very brackish water. The supply is, I believe, less than in the other well, but I have no certain information.

Another circumstance worthy of note is referred to by Mr. Hope in his letter No. 2280 of 1871. A well was sunk at the Surat race-course about half a mile outside the city walls, at a spot in the middle of four existing wells, none of which are more than 150 yards apart. All these wells are comparatively sweet, certainly much better than any well inside the town of Surat, yet Mr. Hope's well proved brackish. In this case I think it is to be regretted that the well was not pumped for some time before being abandoned, since the salt may have been derived from the sides of the well and pumping might have caused an inflow from the stratum which supplies the other wells, but the saltness may have been due to the water finding its way into the well by a different channel to that pursued by the flood supplying the others.

* The statement in a report by Mr Sowerby on the water-supply, &c., of Surat, dated 7th November 1868, that, the level of the water in the Surat wells is above that of high spring tides in the Tapti, appears to be incorrect.

With reference to the impurity of the wells within the city walls, it is probable that water percolating through the accumulated debris of old mortar, ashes, burnt clay, &c., which have raised the surface of the ground inside the city from 10 to 20 feet, may dissolve a considerable quantity of various salts, and thus increase the saline ingredients of the well water.

So far as I can judge, however, none of the wells in or around Surat furnish water so pure as ought to be obtained for drinking purposes. I am told that no complete analyses of these waters have ever been made, and I should recommend that such be obtained of different waters, including the best and the worst, since the kind of salt present and the relative quantities may afford some clue to their origin.

The details just given concerning the Surat wells are certainly in favor of the conclusions already expressed as to the causes of irregular distribution of fresh water in the soils of Surat. These conclusions I will briefly recapitulate, pointing out their practical application—

1. There appears reason to believe that the greater portion, if not the whole, of the alluvial deposits near the coast of Guzerat were originally impregnated with salt in consequence of their having been formed in salt-water. Where they are now free from saline impurities, this is due to the removal of such impurities by the percolation of fresh water.

2. Such percolation of fresh water has been efficient in proportion to the elevation above the sea, and to the greater or less permeability of the beds; consequently, as a rule, those wells which are at the greatest height above the sea and those which yield the most water are the sweetest.

3. The distribution of permeable and impermeable beds is very irregular, most of the strata being lenticular in section and thinning out within short distances.

4. It ensues from the above, that there is no reasonable prospect of fresh water being obtained from deep borings, unless the strata beneath the bottoms of the existing wells are generally more pervious than those near the surface. This is possible, but there appears no sound reason for anticipating that it will prove to be the case, and it is probable that deep borings will give as irregular results as surface wells.

5. It is also improbable that fresh water will be found in wells sunk in the salt lands now being reclaimed. Should such be found, its occurrence will be, I think, accidental, and due to the existence of unusually pervious strata, and I think that these may very possibly prove local.

6. The presence of fresh water in some places on the coast, as near Dumas and at Vaux's tomb, appears due to the existence of sand-hills resting on impervious clay. The quantity of water will probably bear some proportion to the extent of the sand-hills. Although a considerable supply may be derived from such places for local purposes, I do not think it probable that the quantity is sufficient to supply large irrigation works, nor should I be surprised if in some similar localities the water proved more or less brackish, owing to the presence of salt in the sand, or contamination from the subsoil. Deep wells amongst the sand-hills would probably yield brackish water.

7. None of the wells about Surat town supply really good water, nor is there at present sufficient prospect of improvement to justify the sinking of deep wells, and, as an ample source of excellent water exists in the river Tapti a few miles higher up, and I am informed that it is proposed to introduce the same into the city, it appears scarcely worth while to incur expense in experiments which are very likely to fail.

Finally, I can only suggest that if further information be required, and to test the accuracy of the views here expressed, borings should be made to a depth not exceeding

150 to 200 feet. To attempt to raise water from a greater depth would probably involve greater expense than the value of the water for irrigation would cover. It would be well to make borings along lines, and at a fixed distance apart, in such parts of the district as it is particularly desired to explore. There appears no reason for selecting any locality in particular, for, as I have above shown, the probability appears to me that sweet water will not be found, at all events not as a general rule; at the same time, the matter is of such importance that the trifling cost of a few borings would be fully justified in order to obtain certain information, for, after all, the opinion given above is based upon very imperfect information.

When borings are made the water from every water-bearing stratum traversed should be separately tested, and, at all events, the quantity of salts in solution ascertained by evaporating to dryness, care being taken that some water is always pumped out before collecting specimens for analysis.

I would further recommend that complete quantitative analyses be made of a few of the Surat waters, especially of those in and near the town of Surat,* and I would also suggest that the water of some of the wells which are said to be gradually becoming salter be analysed, or, at all events, the quantity of salts in solution estimated (a very easy matter) from time to time.

As already pointed out, common salt is by no means the only impurity present in considerable quantities in the well water of Surat, and other salts may be equally deleterious both to human health and to vegetation, although their presence is not so easily detected by the taste of the water. It is useless, without more exact information as to the nature and quantity of these salts, to attempt to trace their origin; some have, in all probability, been derived, like the common salt, from the sea; others from the decomposition of the materials forming the alluvial strata.

11th January 1875.

SKETCH OF THE GEOLOGY OF SCINDIA'S TERRITORIES, *by* H. B. MEDLICOTT, A. M., F. G. S., *Deputy Superintendent, Geological Survey of India.*

Configuration.

Scindia's possessions are so scattered, that any connected physical description of them must include much adjoining ground. The extent and uniformity of the natural features further involve this comprehensiveness, so that the following notice of the geology of the region comprises much of Holkar's territory, all of Bhopal and of the British district of Ságar, all of Kotah, a great part of Búndi, besides some other petty States of Rájputána. All this ground belongs to the Vindhyan plateau, defined on the south-south-east by the Vindhyan range overlooking the Narbadá valley, on the north-east by a scarp overlooking Bandélkand, and on the north-west by cliffed ranges facing Rájputána. Although its limits are so well defined, the character of this area as a single plateau is not well marked. The entire drainage is from the southern edge, the crest of the Vindhyan range; and in their progress to the Jamná the rivers have formed deep and wide valleys, so that a very large area of the so-called plateau consists of plains but little raised above the level of the country to the east and west: still the plateau form is everywhere maintained; the smallest elevations are little table-lands or terraces.

* It should be borne in mind that the greatest care is necessary in collecting samples of water for analyses; such samples should be taken by a responsible officer personally, never on any account by a native servant or subordinate, and both bottles and corks must be perfectly clean. Unless these precautions are taken, the analyses when made will be useless.

Structure.

2. These features are directly connected with the rock-structure. The well known geographical name for the southern crest of elevation has been adopted for the great sedimentary formation which forms the basis of the whole plateau. Except along the edges of their area, the Vindhyan strata are horizontal; and this arrangement, combined with alternations of hard and soft rocks, induces the flat scarped form of elevation. In the south-west part of the plateau in Málwá, where the Vindhyans are so completely covered by eruptive rocks, the same form of elevation is constant, illustrating admirably the step-like arrangement for which the name of trap-rock was originally given to these ancient volcanic products.

Superficial deposits.

3. To proceed in regular order from the youngest to the oldest formations, brief notice must be taken of the superficial deposits. There is little or no ALLUVIUM proper in this country, actual land-formation now in progress from river deposits; unless we are to include under this head the almost ceaseless and everywhere present action of wind and rain in shifting and arranging the earth particles at the surface. The soil and subsoil covering is on the whole inseparable from the thick accumulations of clays, sands and gravels occurring over the plains and valleys; although the great depth of these and their forming steep banks high over the extreme flood level of the great rivers, clearly point to conditions of formation separated from the present by marked physical changes, involving a lowering of the water-level in this region. In confirmation of this observation, we find these deposits continuous with those of the great Gangetic plains, in which the remains of extinct varieties of large mammals have been found. The best known locality for these fossils is near Etáwá in the bed of the Jamuná, close to the north-east limit of Scindia's territory. It is very likely that similar remains might be found within the boundary in the Chambal and other large streams.

The Deccan trap.

4. The trap-rock of Málwá is the next in order of age to the valley-deposits, the break in time between them being enormous, embracing nearly the whole of the geological period known as TERTIARY. The formation is known as the Deccan trap, this rock in Málwá being in unbroken connection across the valleys of the Narbadá and the Tapti, with that forming the great plateau of the Deccan. The upper limit of age for the formation is given by the occurrence of NUMMULITIC strata resting upon a denuded surface of the trap along the western base of the highlands near Broach. The lower limit of age is FIXED by the occurrence of CRETACEOUS rocks, supposed to be middle cretaceous, beneath the trap at Bágh in one of Scindia's outlying districts in the Narbadá valley, and also on the plateau near Jábná. Within the formation itself there occur local intertrappean beds, patches of sedimentary rock, earthy and calcareous, frequently containing fresh water fossils. The independent evidence of these has been thought to connect the trap more with the tertiary than with the secondary epoch. The trap belongs to the basaltic family, but presenting many varieties from greenish black, dense, columnar basalt, to porous amygdaloids with agates and zeolites, and to earthy ash-like beds. Within the district under notice no dykes have been observed, showing that it is beyond the immediate region of eruption. The present northern limit of the trap is an irregular line between Nímach and Badráwás. It is purely a boundary of denudation, and it would be impossible to say how much farther to the north the eruptive rock may originally have extended. The laterite band which is so generally associated with the trap may give a clue to this question. There are many kinds of laterite of different ages and modes of origin. The variety here spoken of is a purely earthy ferruginous rock free from sandy detritus, its upper part, to a depth of ten to twenty feet, being intensely hardened by the segregation of the iron. It appears as a capping to the highest plateau of the trap, thus having the apparent relation of an original

top-rock to the formation. If it could be legitimately taken as thus related to the trap, we could assert that this rock had never covered the whole surface in the neighbourhood of Gwalior, for laterite of this type caps the high hill eight miles south-west of the city resting on the Morar rocks, without any intervening trap. A full half of Scindia's territory is on the trap formation. The laterite is finely developed about Guná and Augar.

Cretaceous rocks.

5. Mention has already been made of the small patches of rocks of middle(?) cretaceous age in the Narbadá valley about Bágh and on the plateau near Jábná, both places in or near the Chujerrá district. The most important rock of the group is a limestone holding marine fossils, and underlaid by sandstone, or resting upon the basal crystalline rocks. The infratrappean or Láméta limestone and sandstone of the districts to the east (Ságar and Jábalpúr) are thought to represent the Bágh beds; but as yet only vertebrate remains, some of great size, but unidentified, have been found in them. This information is given because the ground under description has been only partially examined, so that representations of either group might be looked for anywhere at the base of the trap.

The Vindhyan formation.

6. There is an immense geological gap between the cretaceous beds and the Vindhyans, which are the next oldest rocks in this region. In other parts of India this gap is partly filled up by the great rock series of which the Indian coal measures form a part. Geologically, the Vindhyan plateau is a basin. The lower strata of the formation only appear along the boundary of the field, with a greater or less slope towards the centre in which direction younger beds succeed. The whole series has been divided into the following groups :—

Bhanrér ...	Upper Bhanrér ...	Upper Bhanrér sandstone.
	Lower Bhanrér ...	Sirbu shales. Lower Bhanrér sandstone. Bhanrér limestone. Ganúrgarh shales.
Riwa ...	Upper Riwa ...	Upper Riwa sandstone.
	Lower Riwa ...	Jhíri shales. Lower Riwa sandstone. Panná shales.
Kaimúr ...	Upper Kaimúr ...	Upper Kaimúr sandstone. Kaimúr conglomerate.
	Lower Kaimúr ...	Bijigarh shales. Lower Kaimúr sandstone.

7. Most of these groups are represented in Scindia's territories north of Badrawás. The Kaimúr conglomerate and its overlying sandstone are admirably exposed about Gwalior. In the fort-hill and the adjoining scarp they rest upon one of the trappean bands of the Morar group. In the hills to the south they rest upon other beds of the same series. Passing north-westward the Panná shales are found in the low ground along the base of the next scarp, which is formed of the Lower Riwa sandstone. Beyond this again there is a third scarp formed of the Upper Riwa sandstone with the Jhíri shales at its base. Still further to the west we find the Ganúrgarh shales and Bhanrér limestone well exposed in the valley of the Chambul, the Lower Bhanrér sandstone forming the Dholpur ridge on the left bank of the river. In the Nimach district the same series is well developed ascending from the west. The Bhanrér limestone is well exposed between Nimach and Chittorgarh. The age of the Vindhyan series is still quite undetermined. All that can be said is that it is greatly more ancient than the base of the coal measure series. Although so undisturbed and unaltered, and apparently so adapted by their varied composition and the conditions of deposition (as indicated by the variety and prevalence of water-marking), for the existence

and preservation of organic forms, the Vindhyan strata have as yet yielded no fossils. Fine building material is procurable from all the sandstones of this formation. Its most famous product is the diamond, the occurrence of which seems to be limited to the shales near Panna.

8. The most varied and instructive geological sections in all Scindia's territories are in the immediate neighbourhood of Gwalior itself, where the Vindhyans are in contact with the rocks next to them in age occurring within our area.

The Gwalior Series.

It would be impossible to find a better example of unconformity of strata. The lower rocks have not undergone any great disturbance, little more than the Vindhyans themselves, being still in approximate horizontality; but scarped valleys of erosion are found in them filled with thick masses of (Kymore) Kaimur conglomerate and sandstone, the former being principally made up of angular debris of the subjacent strata. These rocks have been called the Gwalior series. The boundary of the Vindhyans passes close to the west of Gwalior, with a general north-easterly direction; and the Gwalior series occupies a comparatively small area between the Vindhyan scarp and the river Sind, forming low east and west ranges of hills. The southern range is fifty miles long, and unbroken, being formed of a strong quartzite-sandstone, the bottom rock of the series, and known as the Par sandstone. This group has the same relation to the gneissic area of Bandelkand as have the Kaimur strata. Both present scarps towards the low ground of crystalline rocks, out of which the under-cliff is formed; the irregular surface of junction between the Par sandstone and the gneiss slopes northwards, disappearing up the gorges at a few score yards from the line of the scarp, and so vanishing altogether towards the end of the range, where the Sind forms small cataracts over the Par sandstone at Seonrha. The same northerly slope prevails throughout the series, bringing in higher strata in that direction. The Par sandstone is thus succeeded by a great thickness of very different strata, known as the Morar group. These have some decided characters common throughout—finely laminated shales and flags, often highly ferruginous and very commonly banded with layers and nodules of jasper and hornstone. Two very marked breaks occur in the uniformity of this group, owing to the intercalation of great sheets of eruptive rock, apparently of contemporaneous origin; and this has resulted in a corresponding break in the form of the ground. The lower part of the Morar group is found along the north side of the main range of hills. In the irregular valley between this and the broken middle range, the rocks are concealed by alluvium; but at the head of the valley, near the villages of Chaora and Buda, two strong flows of trap are finely exposed. There is just enough evidence to show that the valley is excavated along the outcrop of this trap, it is seen in the stream close to Barori village, and again at the east end two miles west of Behat. This is a very ancient valley; for in the middle of it, near Bastori, there stands a small plateau of Vindhyan sandstone. The plain of Morar, separating the middle range from the very broken chain of flat hills to the north extending eastward from the old Residency, is undoubtedly laid upon the denuded outcrop of the great sheet of trap exposed continuously all round the base of the fort-hill and of the adjoining scarp where it is overlaid by Kaimur sandstone, and which is equally well seen along the south face of the northern hills to be overlaid by the jaspideous shales of the Morar group. There are several scattered hillocks of this same trap over the plain to the east of Morar. Besides the trap, the Morar group contains local bands of cherty limestone. One of these occurs in the hills about the old Residency; another is traceable in many points in the middle range of hills. A very rich earthy iron ore has been extensively extracted from near the base of the Morar group in the southern hills. In the Sind, at the eastern end of the southern range, at a mile and a half above the village of Nardha, there is a vein in the Par sandstone said to contain lead ore (galena).

There is but one other formation to be noticed. Scindiah's territories include a small portion of the crystalline rock area of Bandelkhand. The relation of this rock to the Gwalior and the Vindhyan series has been noticed. The GNEISS is often highly granitoid, but no intrusive granite has been detected. Bands of schists, sometimes hornblendic, occur occasionally, having an east-west strike. The most remarkable feature of this area is the number of great reefs of vein-quartz, forming narrow regular precipitous ridges, with a prevailing north-easterly direction. No trace of gold has ever been noticed about them. The gneiss is also much traversed by trap-dykes; in these a north-westerly direction prevails. They have been found in some cases to traverse the quartz-reefs, and are, therefore, younger than these. But both reefs and dykes are older than any of the sedimentary formations in contact with this gneiss. At the western edge of the trap and Vindhyan plateau, there may be patches of crystalline rocks within the Amjhera and Jawad Nimuch districts of Scindia's territories.

Gneiss.

April 1873.

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14th April, 1875.

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April 14th, 1875.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1875. **[February.**

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1874.

The labours of the Geological Survey of India have been, during the past season, almost entirely under the control and direction of Mr. H. B. Medlicott, who was officiating as Superintendent during my absence on leave. As stated in the report for last year, I remained for some time at Vienna arranging for the proper exhibition of the collections forwarded by the Geological Survey of India; this delay, however, did not tend to the improvement of my health, and I was in consequence not able to return to duty in India at as early a date as I had hoped. My first duty, on resuming charge of the survey, is now to express my high sense of the great zeal and energy with which Mr. Medlicott devoted himself to the duties imposed on him, and the wide knowledge of Indian Geological work and the high intelligence which he brought to bear on the researches of the survey, for which I am greatly indebted to him.

During almost the entire year, in addition to my own absence, the Geological Survey was also deprived of the aid of Mr. W. T. Blanford. He was, during this period, busily engaged in working out and passing to press the results of his examination of parts of Persia, while accompanying the Seistan Boundary Commission as Naturalist and Geologist. These researches, regarding a country but little known, and at the same time so intimately connected with Western India and Sind, will, I have no doubt, prove of very high value and interest to Indian Geologists. Their publication may now be looked for soon. Mr. Blanford resumed his duties on the Geological Survey about the middle of December, and then visited Surat district with a view to advise the authorities on the probabilities of obtaining fresh and good water in many places where now the supply is bad, salt, and brackish. Mr. Blanford has since then proceeded to take up the general examination of the Province of Sind.

Another of our staff who was absent at the commencement of last year, and whose return we looked for with great interest, has fallen a sacrifice to his over-exertion in the cause of science. Dr. F. Stoliczka, who had been, as reported last year, attached to the Yarkand mission under Sir T. Douglas Forsyth, had, though with much suffering, safely accomplished the journey to Kashgar, and had also on his return had a rapid and hurried ride across the Pamir Steppe, which he had often longed to see, and was returning to his work in India laden with rich and valuable zoological collections and with abundant notes to work out his results, when he again felt the extreme temperature of the Karakorum pass. For a couple of days from 16th June he worked on quietly, and though with suffering, continued the usual marches of the party with whom he was travelling. On the afternoon of the 18th, when more than half the day's march had been completed safely, he noticed some-

thing high up on the hill side, which arrested his attention, and dismounting from his horse, which, of course, could not climb up the rugged cliffs of these bare and snow-clad hill sides, he himself with great exertion struggled up, examined what he wished to see, and made his notes, and struggled down again to his companions. They noticed the great difficulty he found in again mounting, and came on to the camp slowly and carefully; the march next day was countermanded, in the hope that a little rest might enable our friend to recover himself, but falling into a semi-unconscious state, he only lingered on until the noon of the following day (19th June). His body was conveyed to Leh, where, with all possible honours, his remains were interred in the presence of his fellow travellers, the officers of the mission.

Thus passed away at the early age of 36 one of the most devoted and able votaries of Natural Science whom India has ever seen.

Gifted by nature with peculiar powers of observation and comparison, trained in an accurate and careful school of Geology and Palæontology, he brought to his labours unbounded zeal, acute intelligence, and large and carefully acquired knowledge, all of which tended to render him one of the most useful and most trusted of our colleagues. But in addition to this, his genial temperament, his sound judgment, and his hearty appreciation of work of any kind in others, together with his clear views of justice, and the unflinching expression of those views, made him also one of our most esteemed and beloved friends and advisers. His loss to the Geological Survey will be long and keenly felt. He has left behind him a noble monument of his research and powers in the Palæontologia Indica, published by the Geological Survey of India, in which, just before his departure for Yarkand, he had completed the description of the Cretaceous Fauna of Southern India in four large volumes 4to., with 203 plates. And fortunately for the Survey, he has also left behind him a very fitting and competent successor in Dr. Waagen, long his trusted fellow labourer and assistant. Dr. Waagen's publications have already secured for him the high approval of all competent to judge of such careful and accurate research.

Dr. Waagen himself was also absent on medical certificate during the year, and has only recently returned to take up the Palæontological labours on which he was so actively and earnestly engaged, when his health gave way. He has, I am happy to say, returned in good health.

Mr. Medlicott's time was so fully occupied by the current work of the survey, and by the pressing necessity for constant revision of the reports and researches of others, and unceasing communication and advice on all points referred to this office, that he found time for only two brief visits to the field. At the urgent request of the Government of Bengal, he undertook to visit the localities where coal was reported to occur within the Garo Hills. Until very recently, it was not possible to proceed into these hills with safety. And when formerly Mr. Medlicott visited the southern fringe of the hills (Memoirs, Geological Survey, India, VII, 151), and described the local exhibition of some poor coal-seams along their outskirts, no repetition of these rocks was known to occur within the range. But on now getting access to them, several detached basins of newer secondary rocks have been found in the heart of the hills, north of the main ridge. In one of these a strong seam of fair coal is pretty generally distributed. An account of this discovery was given in the May part of the Records of the Survey, 1874, p. 58, and it is therefore unnecessary to refer to it more in detail here. A short run into the northern portion of the Rajmehal Hills resulted chiefly in the discovery that no alluvial deposits occurred on the top of Putturghatta Hill north of Colgong, where they had been reported to occur, at a level which made it difficult to account for their existence, excepting on the supposition that the 'old alluvium' of Bengal had a

Mr. Theobald continuing his researches in the upper tertiaries, flanking the north-western Himalaya, has made a rapid examination of the area lying between the Ganges and the Ravi. Some of his results, if confirmed by more careful investigation, are of high interest. He considers, apparently on good grounds, that the great mass of the Sivalik range on this side (east) of the Jumna river is really composed of rocks belonging not to the Sivalik group, but to the older and distinct Nahan group, a view in which Mr. Medlicott, who formerly examined this area, is disposed to concur. Trans-Sutlej, Mr. Theobald thinks he has established a northern limit for the Sivalik rocks along the Una dun. These are most interesting results, but as some of the most important palæontological deductions depend on these separations of the rocks in which the fossils occur, they must only be taken for the present as provisional.

Further research has led him to modify the conclusions arrived at in the previous season regarding the pre-Sivalik age of glacial deposits, for he finds typical glacial débris scattered irregularly over the rocks in the typical Sivalik area.

The collection of the very valuable fossils of these areas increases rapidly under Mr. Theobald's hands, and a large number have been received, the majority of which cannot be opened out for want of space in the Museum here.

Mr. A. B. Wynne commenced the examination of the Trans-Indus salt region early in the season. At the special request of Mr. Wynne, Dr. Warth, in charge of the Pind Dadun Khan Salt Mines, was deputed to accompany him, so as to form a sound practical estimate of the commercial value of these extensive salt deposits. Dr. Warth was unable to proceed with Mr. Wynne in the early part of the season, but subsequently joined him on the ground. This work was very well accomplished, and a brief summary of the geological results was at once submitted with the practical report of Dr. Warth. And this was published under the Revenue Department. Before the close of the year Mr. Wynne had completed a detailed descriptive report with full illustrations. And this is now in the press, and I trust will be ready for publication without any serious delay. Besides determining the enormous extent of the rock-salt, the most interesting result is the confirmation, in all probability conclusively, of the supposed old tertiary age of the rock-salt. This idea which had been arrived at during a cursory and preliminary examination in previous years was borne out by the careful and detailed investigation of the past season. No rock older than the salt has yet been noticed, and this salt seems to be intercalated with the lower beds or almost the base of the nummulitic rocks.

During the recess Mr. Wynne was also engaged in revising, and to a considerable extent rewriting, the report on the Salt-range. At the opening of the present season he took the field with the object of working up the country lying between the Salt-range and the Kashmir boundary to the north, and is now engaged in this area. He has sent in a good collection of fossils from the newer tertiary beds of that region, and also some from the small ridge of the Khárián or Pabbi hills on the east of the Jhelum river.

Mr. King, though unavoidably late in taking the field, in consequence of being detained at Vienna, has made, during the season, good progress in following up the interesting questions to which reference was made in the report of last year. He establishes three zones in the Rajmehal series: the uppermost characterized by a marine fauna recognized by Dr. F. Stoliczka as corresponding to his 'Oomia' beds in Kachh; a middle zone also containing marine fossils of somewhat different form from the preceding, and a lower zone with well marked Rajmehal plants. This last is found to be closely superimposed, but with general unconformity, upon beds containing plant remains belonging to the Kampti-Damuda flora, thus leaving little or no room for the zones which elsewhere are thought to intervene

between these two formations. Mr. King's work includes a large portion of sheet 94 of the Indian Atlas, but unfortunately the northern portion of this sheet is still unsurveyed topographically, or rather the topography is not yet published.

The exploration of the Beddadanole coal-field was continued under Mr. King's direction with the assistance of Mr. Vanstavern. Some bands of poor coal and coaly shale were proved in the lower parts of the measures. The upper portion has not yet been proved; yet it is there, according to the analogy of the Wardha fields, that the main coal is likely to occur, if at all. This portion will be tested on Mr. King's return from his present duty, and on Mr. Vanstavern returning from the Juggiapettah borings. These have been put down alongside those formerly made by Colonel Applegath, and where he believed he had found coal, but Mr. Vanstavern has not been able to trace any proof whatever of the existence of coal or of any similar substance, although his borings have been carried below the depth to which the previous one had proceeded. All these borings have since been carried down to the metamorphic or sub-crystalline rocks *without a trace of coal.*

Mr. King has been diverted from the systematic continuation of his work for the present season to examine the gold-bearing reefs of the Wynâd, and is at present actively engaged on this work.

Mr. Foote accomplished a heavy season's work in the Southern Mahratta country, completing the examination of the quartzite series of that region. Considerable progress has been made in preparing for publication a detailed description of this area. Mr. Foote also examined so much of the adjoining country as enabled him to complete the northern half of sheet 41 of the Indian Atlas, and the north-west quarter of sheet 58. In the preparation of these maps also considerable progress has been made.

At the close of the season, Mr. Foote made an examination of the small gold-bearing tract in the Dambal hills of Dharwar. Of this a report with small map has already appeared. (Records, Geological Survey, November 1874). The smallness of the area and the sparing distribution of the metal seem to offer but little inducement for any large outlay of capital in gold mining or washing.

At the close of the recess Mr. Foote took up the country north of Madras town in order to complete the area lying between the hill ranges and the sea (in sheets 76, 77, and 95), also to close in a large portion of that country. This had been left while urging on the examination of the Kadapah and Karnul districts, as being of less pressing importance at this moment.

Mr. Hughes has again been largely called upon for investigations which are not purely geological, and which very seriously interfered with the systematic progress of the survey. These have been chiefly in connection with the prospects of establishing the manufacture of iron in various places. At the close of last year he had just completed a re-examination of the available ores and associated rocks of Kumaon; this examination only confirmed the views expressed years since by the Geological Survey as to the abundance of ore and flux, and as to the probability of their being also a good supply of fuel for operations upon a limited scale. He is disposed to take a rather less favourable view of the richness of the ores, but this was always the view of the Geological Survey; the great tractability of the ores to a good extent compensating for a certain poorness in quality.

Mr. Hughes was then detained to revise the examination of parts of the Raniganj field, with a special view to the advantages offered by it as a locality for the smelting of iron, and establishment of iron works on a large scale. On these points full reports have been published during the past year in the Records of the Geological Survey.

These investigations detained Mr. Hughes, so that he did not get to his regular work until late in January. With Mr. Fedden's aid he then remapped the northern portion of the Wurrora coal-field, taking advantage of any recent exposure of the rocks in order to revise his geological lines. In a country so largely and thickly covered with alluvial deposits, it becomes necessary to pick out every single point so as to obtain any clue even of a trivial kind which may lead to the identification of the various rocks so badly seen. And this Mr. Hughes appears to have done with much care. It is gratifying to find that the practical conclusion based solely on such geological investigations, as to the existence of coal in the neighbourhood of Bander, has been fully confirmed by actual borings commenced entirely on Mr. Hughes' recommendation. These borings have proved the existence of coal many feet in thickness, the occurrence of which would never have been suspected from any surface exposure of the beds. This fact becomes of higher importance, because the locality of this coal is greatly nearer the very valuable iron ores of the country than any previously known beds of coal in the Wardha valley fields.

Passing into the Berars and the Nizam's territories, Mr. Hughes continued these investigations, and was able to give important advice and aid to the Nizam's officers.

It is a source of much regret that in consequence of the frequently recurring and continued interruptions to Mr. Hughes' progress in that district, the mapping of this Wardha coal-field is not yet completed. There is still a considerable area calling for careful examination, and in which it is not improbable that valuable results may yet reward our search. It would only cause greater delay to put any one else to complete this work now. And we can therefore only hope that it may yet be practicable without any much prolonged delay to complete the examination. The very existence of true coal in these districts and the sound knowledge already obtained of its extent and amount is altogether the result of the labours of the survey, and we should be glad to complete the investigation of the rocks as soon as practicable.

Towards the end of the year Mr. Hughes' aid was again sought for by two separate companies, who have undertaken to remove the all-important trial of actually smelting iron in this country from the field of speculation and writing to that of actual experiment on a commercial scale, in order to point out to them the most favourable localities for the procuring of ores, coal, &c., &c. He had scarcely concluded this work when the year closed. He will thus again have only a brief season to devote to his systematic work. He will, I am sure, do all that can be done in the time, but it will be entirely impracticable to complete the field in one short season.

Mr. Fedden, who, as stated in last year's report, had been absent on sick leave, did not return to work until late in January, 1874. He then joined Mr. Hughes in the Wardha valley field, and worked with him for the remainder of the season, putting in the detailed geological lines in parts of the Chanda district and in the adjoining territories of the Nizam. At one place north of Wurrora, Mr. Fedden was fortunate enough to discover a few specimens of fossil fishes in the uppermost beds of the sedimentary rocks, at about the same horizon as that on which the Reverend Mr. Hislop years since found similar remains. These will doubtless prove a valuable addition to the limited evidence we already possessed on which to base a conclusion as to the age of these beds. Mr. Hislop classed these rocks as belonging to the infratrappean beds of that neighbourhood in which he states that he found shells of the same kind as from the intertrappean layers, mixed with bones of large animals. On this evidence he referred the rocks to the same age relatively as the Lameta beds of the Narbada valley.

During the current season Mr. Fedden is attached to Mr. W. T. Blanford in Sind.

Mr. V. Ball only returned from the great exhibition at Vienna, where he had been, jointly with Mr. W. King, in charge of the valuable collections of the Geological Survey, late in the year. After some few unavoidable delays which prevented his getting to the field till towards the end of December, he was again frequently interrupted in his work in connection with the borings in the Dudhi valley. His survey labours were confined to the country included in sheets 17 and 18 of the Satpura Survey. He had made some progress in this area, when at the beginning of March, he was suddenly summoned to Calcutta, with a view to his accompanying some others on a visit to the Mergui Archipelago. This trip was subsequently abandoned, nor indeed under any circumstances could geological results of interest be looked for from such a visit to a country already examined. It was useless his returning to the field again after this trip was given up. Mr. Ball had thus only a very brief season of work, scarcely more than two months out of the whole season. It would scarcely be fair to look for any large outturn of work in this short time. The ground on which he was engaged was difficult, and the intricate relations of the various groups of rocks must all be more thoroughly elucidated and worked out before any descriptive account of them can be published.

Mr. Ball subsequently visited the wild district of the Luni Puthans, west of Upper Sind, where some traces of lignite had been seen. A full account of this visit has already appeared (Records, Geol. Surv., Ind., 1874, p. 145), so that it will be unnecessary to refer to it here in detail.

The experimental borings for coal in the region of the Narbada have not yet led to any discovery. Early in the year two borings were commenced, at Khapa and at Manegaon, in the valley of the Dudhi. These were in the Mahadeva rocks, and were put down in the hope of striking the coal-measures beneath. At the beginning of the monsoon these borings had reached 260 and 241 feet respectively from the surface, and were still in the covering rock formation, when the work was necessarily closed for the season. The labour was then transferred to the boring at Sukakheri in the main valley, where a depth of 344 feet had already been reached. There, it may be noticed, the endeavour is to reach the rock underlying the valley deposits, there being some grounds for supposing that the coal-measures of the Sitariva extend to the north. This boring has been carried down to the depth of 491 feet still in the stiff kunkur clay. The 3-inch piping having stuck fast at 425 feet, the additional depth was attained with great difficulty, until finally it was found impossible to do more than draw the sludge filling in from the sides; and the work had to be stopped. This boring had been commenced with such material as was available at the time, and with the full expectation that rock would be reached at a less depth. It had also the further disadvantage of frequent interruptions from want of piping; much credit is, therefore, due to the skill and energy of Mr. Stewart, that he was able under the circumstances to push the work so far.

No direct knowledge has, however, been gained upon the question to be solved excepting collaterally, that it would certainly be very costly to sink for coal through such a depth of superficial deposits. It may possibly be that these deposits are exceptionally thick at Sukakheri, and that rocks may be nearer the surface elsewhere, and the question would seem of sufficient importance practically, and of sufficient general interest to warrant a renewal of the trial in another spot. The lowest few feet of clay in the boring at Sukakheri were much charged with black ferruginous granules, single and agglomerated, suggesting perhaps the proximity of a lateritic bed which is by no means uncommon at the base of the old alluvial deposits, and this again most frequently occurs where the trap rocks occur underneath. Both these conditions are seen to obtain at several points along the margin of the valley.

Since the stoppage at Sukakheri near the close of the year, work has be[illegible]ed at Khapa and Mahegaon, and progress has been already made beyond the dep[illegible] before stopping for the monsoon. In December also two new borings were com[illegible] Tawa valley, at Kesla and the Suk Tawa: the latter is certainly in the Dámu[illegible] rocks; the former is in lower Mahadeva beds. The hope is to strike the Barakur coal-measures, and thus, if coal be found, to save twenty miles of rough carting from the Shapur or Bétul coal-field to the south. As has already been fully explained, it is impossible to speak of success as anything more than a chance, inasmuch as no outcrop of these measures is seen north of the Shapur field.

Mr. Willson steadily continued his mapping of the northern portion of the Bundelkund Survey and finished several sheets of the 1-inch plans. One of the principal points of interest connected with this area is the great prevalence of quartz reefs or veins, having a very constant and definite direction and occurring in large number and of great size. There are also two systems of trap dykes in considerable number, and Mr. Willson finds evidence, which seems almost conclusive, that both these systems of trap-dykes are younger than the great quartz reefs, a conclusion of the highest interest as bearing on the geological history of the district. Mr. Willson has again resumed this work for the coming season. Mr. Willson's mapping is always distinguished by care, neatness, and accuracy.

Mr. Hacket resumed his labour in Rajputana, mapping in a large area of the country lying between Bhurtpur and Jaipur, and to the south, included in the sheets 27, 35, 37, 38, 39, and 41 of the Rajputana Survey, and in parts of 10*a*, 10*b*, and 12 of the Gwalior Survey, (scale 1 mile = 1 inch). All the rocks met with belong generally to the samec lass as those previously described by Mr. Hacket in the Biána hills, being chiefly quartzites, with very irregularly intercalated zones of schists, limestone, and trappean rocks resting upon or against gneissic masses. Mr. Hacket is disposed to adopt the name attached to the general range of those hills as a general inclusive name for the whole series of rocks, and to call them the Aravali series.

This work will be continued on Mr. Hacket's return from furlough, on which he is now absent. It has been for some time anxiously looked for, as tending to fill in one of the great *lacunæ* on the map of India, with a view to a general geological sketch of the country, and one of such importance that nothing very satisfactory can be done towards such a map until this portion of the country has been examined.

Mr. Mallet accomplished the examination of Sikkim (British) and of the Western Dhuars. The interest attaching to this field, from the probability of the coal forming an useful source of fuel, led to the publication of Mr. Mallet's report as quickly as possible. It has been issued with two geological coloured maps. Excepting in the Darjiling district his examination had to be limited to a mere fringe of the mountains; in places, indeed, even this much is beyond reach of the British boundary. There would appear to be some prospect of the Dámuda coal of that region being made serviceable by the adoption of suitable contrivances for the utilization of such dust or powdery coal.

Mr. Mallet's observations have led him to the conclusion that the Dámuda formation is, in this country, the lowest member of the rock series of the outer Himalaya ranges, the Darjiling gneiss being the topmost and youngest member of the same series. This, if confirmed, is a result of very great interest and importance, and would tend to establish a well marked common horizon between the rocks of the Himalaya and those of the Peninsula of India. Mr. Mallet's researches, excepting in the point to which his attention was specially directed, were necessarily rapid and cursory, and the maps can only be viewed as preliminary sketches. Until the country on either side is worked up to this portion, no really trustworthy or reliable section can be obtained from such isolated areas.

e past year there have been four apprentices attached to the Geological Survey e funds granted for that survey. Of these four, one has now been attached r nearly two years. During the present season he has been sent to the field with one of the assistants (Mr. Ball), who reports that up to date he has been attentive and willing to learn, but that his progress is very small and very unpromising. Further experience will be necessary before anything definite can be said as to the future prospect of this student. The other three, although nominated at the beginning of the year and receiving pay as apprentices, have been doing nothing in connection with the Geological Museum or Survey, having been, under the sanction of Government, attending courses of lectures and instructions at the Presidency College. Undoubtedly these lessons will enable them to appreciate better than they could otherwise have done the more technical knowledge which they are expected to acquire here. But the necessity for their devoting considerable time to this acquisition of what must be considered purely preliminary and collateral knowledge preparatory to any study of geology or its bearings, will also undoubtedly prolong the time during which they must be merely learning. It may, I think, well be doubted how far the system of paying young men for learning what they ought to be able to prove their acquaintance with, before their appointment, can be very successful. Certainly the system of giving appointments in order to induce the holders of those appointments to make themselves acquainted with their duties has, in every other scientific pursuit, proved a failure. These student apprentices will be subjected to examination at the end of the season, when their general progress can be tested.

As customary, a small map of India is annexed, showing the present rate and general progress of the survey.

Since the commencement of this survey it has ever been my anxious desire and aim to complete a general sketch map of the Geology of India. The conviction has grown stronger each successive year, that until this can be done, nothing really useful can be attempted in the direction of very detailed geology, and that our progress must necessarily be slow and irregular, until we shall have been able to fix even roughly the boundaries between the known and the unknown. I still hope that I shall be able to complete such a map. But I deeply regret to say that during the last few years, very little advance has been made towards the accomplishment of this end. There have been for some years so many and such urgent claims on the time of the officers of the survey for work of various kinds, often not geological, and the staff of the survey has been so reduced by illness and absence, as well as by actual diminution of numbers, that very little progress has been possible in that which has always been recommended to be, and which has indeed been more than once ordered to be considered the first and main object of the survey, namely, the systematic and continuous survey of the country. I am fully aware of the value of the results often obtained from enquiries in isolated areas, and at detached and separate points. Striking instances of this might be given from last year's work. Yet I am also compelled to think that these isolated enquiries are rarely of such immediate and urgent importance as to counterbalance the great and heavy disadvantage resulting from this very fact of their isolation. Each becomes a separate individual case, which it is impossible to colligate into a whole simply because we have no knowledge of the connecting links in the chain. Indeed many cases might be given where it seems more than doubtful whether anything is really gained even in time from such necessarily imperfect and unfinished results. A few years of devotion of the greater portion of the staff of the survey to this one object would enable such a general preliminary map to be published, subject of course to additions or corrections as the more detailed work progressed in future years.

A glance at the little map which accompanies this report will at once show what large areas there are regarding which the Geological Survey of India as yet knows nothing of

its own research. But the difficulty in compiling a general map much on the size or frequency of these gaps or *lacunæ*, for, of course, the to be filled in afterwards, but on the fact, that without some knowledg[illegible] vening spaces, it is impracticable to correlate the rocks in one part of [illegible]y with those elsewhere. Each district or area examined in itself is necessarily described b[illegible] itself, the rocks which occur in it are reduced to a system, their succession traced out, and their relations one to the other determined so far as possible. Local distinctive names are given to such separate groups, and all is rendered as complete as may be possible *for that area.* The survey operations are meanwhile directed to some other locality, and the same process of examination is gone through, but the results are not exactly the same; new sub-divisions of the rocks become necessary, new names are given to distinct groups, for local convenience of description. This result is equally correct and equally satisfactory for its own area. But for any general map, it becomes essential that all these differences should be eliminated, however roughly, and all reduced to one general system or scale, and this is precisely what it is impracticable to do without some knowledge, however imperfect, of the country generally, which knowledge there is no means of obtaining while the officers of the survey are engaged in isolated localities and on special researches.

Seeing then the very distant prospect which was before the survey of being able to work out any general map from their own researches, I have for some years devoted much attention to preparing separate descriptions and in some cases separate maps of certain divisions of the country, so far as these were possible. Passing over papers descriptive of the general geology of districts, or collectorates, (such as Surat, Gwalior, neighbourhood of Madras, Godavari, &c.,) a general sketch of the Geology of the Central Provinces was given so long since as 1871, of Orissa in 1872, of the Bombay Presidency in 1872, of the North-Western Provinces in 1873, of part of Punjab in 1873, and a general sketch of the Punjab is now just ready for press, while a general sketch of Bengal will be taken up also. These are all in addition to the regular and more detailed descriptions of separate areas, coal-fields, &c., &c. The most cursory reference to these sketches will show the impossibility of combining all into one system, without more knowledge of the intervening areas, as yet unexamined, or, as the other alternative, reducing the map to such large generalities as would get rid of these minor difficulties, but would at the same time make such a map of extremely little value.

It is our earnest hope, however, that the survey will be permitted to complete such a general sketch map as may prove useful and within a limited time.

PUBLICATIONS.—Of the MEMOIRS of the Geological SURVEY OF INDIA, Vol. X, part 2, announced as nearly ready at the close of last season, was issued early in the year. This contained a descriptive account of the Geology of Pegu by Mr. Theobald, with map, &c. And at the close of the year, part 1 of Vol. XI, containing a report by Mr. Mallet on the Geology of Darjiling and the Western Dhuars, with two geological maps, &c., appeared.

Of the RECORDS of the Survey, the usual quarterly publication was steadily maintained, and the volume for 1874 contains no less than twenty-three separate papers on varied points in the Geology of India. Four of these are valuable summaries of the geological results obtained during the visit to Yarkand with the mission recently returned from that country by our lamented colleague, Dr. F. Stoliczka. These with the note on the Altum-Artush, which will be found below, complete all that he had brought into shape for publication. Of practical papers, there are notes on the iron ores of Kumaon: on the raw materials for iron smelting: on Petroleum in Assam: on the subsidiary materials used in production of artificial fuel: on the building and ornamental stones of India: on Potash salts: on Manganese ore, &c., &c., while descriptive notices are given of parts of Northern Hazaribagh; neighbourhood of Murree; of Kangra; of the Garo hills; of the Luni Puthan country west of Sind,

uthern Godavari country. These with annual report, and an interesting paper ld, on some speculations as to the antiquity of the Human race in India based nds, form the volume for the year.

ONTOLOGIA INDICA, only one part was actually issued during the year 1874. As already stated in previous reports, the concluding parts of the Cretaceous Fauna of Southern India had been pressed forward in anticipation of their regular time of issue in order to complete this valuable series before the writer, Dr. Stoliczka, went away. This series was issued in full for the year 1873. And in addition, the commencing part of the Cephalopoda of Kachh by Dr. W. Waagen was published in anticipation of the regular time of issue, namely, for the first quarter of 1874. The absence with the mission to Yarkand of Dr. Stoliczka, and from ill health of Dr. W. Waagen, has prevented further publication during the year. Progress was, however, made in the preparation of plates and drawings, and since the return of Dr. Waagen, the continuation of his detailed descriptions of the Kachh Cephalopoda has gone to press. The part issued contained full description and figures of a very interesting form of Rhinoceros (*R. Deccanensis*) found by Mr. R. B. Foote in fluviatile deposits in Belgaum.

LIBRARY.—One thousand and eighty-four volumes or parts of volumes have been added to our Library during the past twelve months. Of this total more than one-half, or five hundred and fifty-seven, have been presented by different Societies and other institutions in exchange for the publications of the Geological Survey of India, or as donations, while five hundred and twenty-seven have been purchased. The usual quarterly lists of these have been regularly continued in the RECORDS of the Survey, and as customary, a summary of the various institutions from which donations or exchanges have been received during the twelve months is appended. We continue to render access to this very valuable library as general and as easy, as is consistent with the preservation of the books. And in very many cases, we find that from the special character of our collections, books have been available here, which could not be referred to elsewhere, either in Calcutta or indeed in India. In geological matters, quick and ready reference to the published results of other enquirers is perhaps more essentially necessary than in most other scientific enquiries, and we continue to look most anxiously for the transfer of our collections to premises where they can be rendered more easily accessible, and more generally useful, than it is possible to effect in our present greatly overcrowded apartments.

MUSEUM.—During the year all the collection forwarded to the International Exhibition at Vienna, which was intended to be returned to this country, was safely received back, and was again embodied with the general series. General notices of donations have been given in the Records for the year, while we continue to receive from the officers of the Survey itself valuable additions constantly. Of the so-called Sivalik fossils, a large and valuable series has been procured by Mr. Theobald in his recent examination of the country. The examination in detail of these is, I regret to say, almost completely impracticable from want of any space or room in which to open them out, though individual specimens have been taken up. But very important results bearing on the sub-division and age of the different horizons of these rocks and of the imbedded fossils will undoubtedly arise, as soon as they can be carefully compared and described. From Mr. A. B. Wynne also a good series of similar fossils have been obtained, procured from parts of the Rawal Pindi and Jhilam districts in which he has been working, and from the small range of hills on this side the Jhilam, called the Pabbi hills. Some fish remains and other things were procured by Mr. Fedden, and a good series of specimens from the upper, secondary, and tertiary rocks of the Lower Godavari basin by Mr. King. To Mr. Hughes also the Museum is indebted for a very interesting series of fossils from the country adjoining the Milam pass, to the north of Kumaon, which prove the continuity of the formations first described as occurring near the Niti pass by Colonel R. Strachey; thus extending our knowledge of these formations considerably north-east. The fossils represent at least five different formations, Cretaceous, Jurassic, Triassic,

Permian, and Carboniferous and Silurian. A detailed list will be given in a future number of the Records.

METEORITES.—Our series has been enriched by pieces of the fall which took place on the 23rd September 1873. These are of much interest from the fact of their having been procured at different places, though the structure and composition of the stones show that they are identical in their nature. One piece was found near the village of Mylsi, fifty miles to south-east of Múltan, and two others at Khairpur, thirty-five miles east of Bhawulpur. The distance between the two places being probably more than ten miles.

The collections have been kept in good order and safety during the year.

T. OLDHAM,
Supdt. of Geol. Survey, India,
and Director of Geol. Museum, Calcutta.

CALCUTTA,
January, 1875.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1874.

BATAVIA.—Royal Society of Batavia.
BERLIN.—German Geological Society.
DITTO.—Royal Academy of Sciences.
BONN.—Naturhistorischen Vereins.
BOSTON.—Society of Natural History.
BRESLAU.—Silesian Society.
BRISTOL.—The Naturalists' Society.
BRUSSELS.—Royal Academy of Science.
CALCUTTA.—Agricultural and Horticultural Society.
DITTO.—Asiatic Society of Bengal.
CAMBRIDGE, MASS.—American Academy of Arts and Sciences.
DITTO.—Museum of Comparative Zoölogy.
CAMBRIDGE.—Woodwardian Museum.
COPENHAGEN.—Royal Academy.
DIJON.—Imperial Academy of Dijon.
DRESDEN.—The Isis Society.
EDINBURGH.—Geological Society of Edinburgh.
DITTO.—Royal Scottish Society of Arts.
DITTO.—Royal Society.
GLASGOW.—Geological Society of Glasgow.
DITTO.—Philosophical Society.
GÖTTINGEN.—The Göttingen Society.
LAUSANNE.—The Society of Natural Sciences.
LIVERPOOL.—Literary and Philosophical Society of Liverpool.
LONDON.—British Museum.
DITTO.—East India Association.
DITTO.—Geological Society of London.
DITTO.—India Office.
DITTO.—Royal Institution of Great Britain.

LONDON.—Royal Society.
DITTO.—Royal Geographical Society.
MANCHESTER.—The Manchester Geological Society.
MELBOURNE.—Royal Society of Victoria.
MOSCOW.—Imperial Society of Naturalists.
MÜNICH.—Royal Bavarian Academy of Science.
NEUCHATEL.—Society of Natural Sciences.
NEW HAVEN.—Connecticut Academy.
NEW ZEALAND.—Geological Survey of New Zealand.
PARIS.—Geological Society.
DITTO.—L'Administration des Mines.
DITTO.—National Institute of France.
DITTO.—The Academy of Sciences.
PEST.—Royal Geological Institute of Hungary.
PHILADELPHIA.—Academy of Natural Sciences.
DITTO.—American Philosophical Society.
DITTO.—Franklin Institute.
ROME.—Geological Commission of Italy.
SALEM, MASS.—Essex Institute.
DITTO.—Peabody Academy.
STOCKHOLM.—Bureau de la Recher. Geol. Suede.
ST. PETERSBURG.—Imperial Academy of Sciences.
TASMANIA.—Royal Society.
TOKEI.—Geological Survey of Yesso.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VICTORIA.—Government Geological Survey of Victoria.
DITTO.—Ditto ditto ditto, Mining Department.
VIENNA.—The Vienna Academy.
DITTO.—K. K. Geologischen Reichsanstalt.
WASHINGTON.—Department of Agriculture, U. S. A.
DITTO.—Smithsonian Institute.
DITTO.—United States Geological Survey.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—German Natural History Society.
ZÜRICH.—Natural History Society.

Governments of Bengal, Bombay, India, Madras, North-Western Provinces, and Punjab; Chief Commissioners of British Burma, Central Provinces, Mysore, and Coorg; the Resident, Haiderabad, the Surveyor General of India, the Superintendent of the Great Trigonometrical Survey of India, and the Superintendent of the Thomason College of Civil Engineering, Roorkee.

January, 1875.

THE ALTUM-ARTUSH CONSIDERED FROM A GEOLOGICAL POINT OF VIEW,
by F. STOLICZKA, PH.D

(*Veni, sed non vidi.*)

As soon as the most important political business had been concluded by the signing of the commercial treaty by the Amir, His Excellency Mr. Forsyth expressed a wish to visit the renowned tomb of Sultan Satuk at Altum-Artush. The king accorded his permission, and instructed the Hakim Mahomed Khoja to assist us in travelling over the province under his care to whatever extent Mr. Forsyth might desire.

Under the personal guidance of the Envoy, we—Dr. Bellew, Captain Chapman, Captain Trotter, and myself—left Yangishar on the 14th of February, reaching Altum-Artush at a late hour the same day. As an introduction to the difficulties in travelling, our baggage did not arrive till next day, and we had to accommodate ourselves for the night on the carpets of the floor in a spacious but tolerably warm room. A halt of two days was desirable to enable us to make all necessary arrangements for our further movements. However, before I proceed, I shall endeavour to give the reader an idea of the geographical position and limits of the country of which I shall speak in the subsequent lines.

The data are derived from a general survey by Captain Trotter and from information given by the Hakim Mahomed Khoja.

Altum-Artush, which is the chief place of the province, lies approximately in east long. 76° 8′ and north lat. 39° 41′, therefore about twenty-three miles north by east of Yangishar. It is situated in the western part of the Yilak on the Bogos, here called Artush river, and north of a low ridge which separates the Artush valley from the plains. The southern boundary runs along this ridge for about ten miles west of Altum-Artush, and from there almost due north to the crest of the Koktau range; then along this range eastwards of the Belanti pass (east long. 77° 47′ and north lat. 40° 41′), and from thence in a south-eastern direction to the village of Kushtignak, some fifteen miles north of Fyzabad in long. 76° 42′ 30″ and lat. 39° 28′ 30″. From here the southern boundary runs close to the right bank of the Kashgar river, until almost opposite to where the Artush river runs into the plains.

During the first four days we all marched in company up the valley of the Bogos river to the fort Tangitar, about twenty-three miles to the north by west; then to a Kirghiz camp, Bashsugun, in a north-easterly direction; Tugurmatti almost eastern; and Ajaksugun in a south-eastern direction; the directions being from the last camps respectively.

At Azjak-sugun Captain Trotter and I separated from the rest of the party, marching northwards along the road to Ashtifan, to Jaitava, and from thence across the Jigda Jilga in a north-east by east ? direction to the camp at Nibulak, crossing the Nibulak pass, passing a second jilga, and turning then for almost nine miles more northwards to the Belanti pass, beyond which lies the valley of the Kakshal or Aksai river. On our return we passed Ayak-sugun, Karaul, about a mile from our former camp of the same name, and visited Kultislak and Fyzabad, returning to Yangishar on the 3rd of March.

It was not a very favorable time for travelling in these regions, not so much on account of the cold, as in consequence of the heavy falls of snow which appear to occur over the whole of Thianshan during the second half of February and first half of March. During the last few days of February we were almost constantly wading in fresh fallen snow, though on the saline plains it melted very rapidly.

The snow naturally interfered seriously with our observations. However, obtaining even but a little addition to our knowledge of these hills, was a better way of occupying our time than remaining in our somewhat gloomy quarters.

From a geological point of view the trip proved in many respects to be of considerable interest, particularly as supplementing some former observations made more to the west. Although there is not much variety in the rock formations we may distinguish three successive series. The most southern part of the province, along the foot of the hills, is formed of alluvial gravels and sand in whose unfathomable depths are swallowed both the Artush and Sujun rivers, before they can reach the Kashgar daria. Wherever irrigation from the latter is possible the fields appear to be fertile; but in the contrary case, the land is not much more than a mere desert covered with low and scanty scrubs of *Ephedra* Sp.? The marshy grounds along the river are the breeding places of innumerable waterfowl. Brahmini ducks and pintails were already selecting sites for their nests on the 1st of March. The latter must have only just arrived.

Where high grass occurs wild pigs are not uncommon.

The second series includes the low hills which extend diametrically from north to south over about thirty miles, while the prevalent strike is from north-east by east to south-west by west. All these lower hills are occupied by Artush beds, of which I spoke in a former communication. They are separated into two groups. The lower beds consist of greenish or reddish clays or sandstones, and the upper ones of coarse conglomerates, which on a hill south of Tangitar have a thickness of about a thousand feet. At their contact both groups generally alternate in several layers. An anticlinal runs almost through the middle of their superficial extent. At the fort Ayak-sugun it is caused by a low ridge of old dolomitic limestones on which the Artush clays and sandstones found a firm support. To the south of it the beds dip at angles of about 40° and 50° towards the Kashgar plain, in remarkably regular and successive layers. North of the ridge, which has no doubt a considerable subterranean extent in an east to west direction, all the beds dip towards north by west at a similar angle. Approaching the higher range more recent diluvial gravels cover most of the slopes. The geological puzzle of finding strata of young beds as a rule dipping *towards* a higher range composed of comparatively much older rocks seems to me to be due, at least in this special case, to the phenomenon that the atmospheric waters which, descending on the crest, flow down the slopes of the high ridge, gradually soften them, and if a subterranean outlet facilitate it the softened beds are worn away. While this process is going on the more distant beds simply subside in order to fill the vacant spaces. In some cases a sinking or rising of the main range, or even an overturn of high and precipitous cliffs, seem to go hand in hand with the action of erosion, but it is not always the case. I hope to illustrate this idea by a few diagrams, partly derived from actual observations on some future occasion.

A third series of entirely different rocks forms the main range of hills which are a continuation of the Koktan range, and in which, more to the westward, are situated the Terek and Chakmak forts. The average height of the range is here between 1,200 and 1,300 feet, single peaks rising to about 1,500 feet. The whole of the southern portion consists, as far as I could see, of carboniferous rocks, in which, however, there is a great variety of structure. The lowest beds are very often a peculiar breccia-limestone passing into regular limestone conglomerate. Above this are beds of solid grey dolomitic limestone, partly massive, partly stratified; the former possessing the character of reef limestone, and portions of it are indeed full of reef-building corals, crinoid stems, and a large *Spirifer*, the sections of which, when seen on the surface, have a striking resemblance to those of *Megalodon*.

North of Tangitar and about Bash-sujun I met in several places great numbers of fossils, but they were so firmly cemented in a calcareous matrix that only a few could be extracted. Among these I could recognise a small *Bellerophon*, *Productus semireticulatus*, and an [illegible]. A new *Terebratula* was also very common. Here about Bash-sujun and Tugur-

matti greenish shales occurred often interstratified with the limestones, beds of which were highly carbonaceous; the shales appeared to be unfossiliferous.

The limestone hills, which, as already stated, are a continuation of the Koktan range, extend in a north-easterly direction the whole way to south of the Belanti pass, where they are overlaid by a particularly well-bedded dark limestone very similar to that containing *Megalodon* north of Chungterek. On this limestone rest greenish and purplish sandstones and shales which occupy the pass and the adjoining hills to the north-west of it; mineralogically these last rocks are quite identical with what we understand under the name of "*Bunter sandstein*," and it is by no means improbable that the Belanti beds are also of triassic age, as they succeed in regular layers those of the carboniferous formation.

A peculiar feature in this part of the hills consists in the occurrence of extensive plains to which the name *jilga* is generally applied. It means originally, I think, merely a water-course, and, on a large scale, these plains may be looked upon as water-courses of former water-sheets. They occur at the base of the high range, and in some respects resemble the *dúns* of the southern slopes of the Himalayas. North of Tangitar one of these large plains occurs within the limestone rocks, being surrounded by them on all sides. It must be about thirty miles long from east to west, and about sixteen from north to south. Several isolated limestone hills and ridges occur in it, and it is drained off by the Bogos and Sujun rivers, the former rising in the south-west, the latter in the south-east corner. The average elevation is about 5,000 feet. The greater portion is covered with a low scrubby vegetation, and, near the rivers, with high grass. The principal camping grounds are Bash-sujun and Tugurmatti. The whole plain, which affords a good pasturage ground, is occupied by about 120 tents of Kirghiz during the summer.

The next jilga is the Jigda Jilga. It differs considerably both in its physical situation and in its general character from the former. It stretches from west by south to east by north for about thirty-five miles, while the diameter of the eastern half is about twenty and that of the western about twelve miles. Save for a few low hillocks it is almost a level plain throughout. On the north-western, northern, and north-eastern side it is bounded by the Koktan range, from which several water-courses lead into it, one about the middle from the north and one from north-east of considerable size, this containing a large quantity of crystalline pebbles; the rock from which they are derived must be *in situ* near the axis of the ridge. A third big stream comes from the east, leading from the Nibulak pass. None of these streams had any water in them. On the south, east, and south-east the plain is bounded by the much lower hills composed of Artush beds, their slopes covered with gravel.

An elevated gap or saddle situated in the south-west corner appears to connect this jilga with that of Tugurmatti. There is no drainage from this jilga; all the water is absorbed by the enormous thickness of sand and mud which fills the entire basin. This accounts for the comparatively rich vegetation which exists in it. There are several stretches of regular poplar forest (*P. nigra* or *P. balsamifera*) up to ten miles long and four to five miles in breadth. Besides which there are several places occupied by regular jungle of *Tamarix*, *Myricaria*, *Ephedra*, and the peculiar wormwood, from the seed of which the Kirghiz prepare *satú*. The *Tamarix* and poplars must absorb during their growth a very large quantity of the mineral salts with which the entire ground is saturated; the wood on being burnt gives out a strong smell of sulphur and chlorine.

The poplar trees are not healthy; they resemble oak trees covered with mistletoe. The branches are short, stumpy, and bushy. It is evident that the trees only exist in consequence of the subterranean moisture. There are a great number of springs through the forest and on its edges, but on account of the level character of the plain no flowing streams exist except where there has been a very heavy snowfall and very rapid melting.

It is satisfactory to observe that within three marches of Kashgar there is such a large supply of wood, though it is by no means good wood. I have already stated that the entire soil is very saline, and it is remarkable to see how snow melts on this saline ground. Thus about four inches of snow fell while we were there. In one day all was melted away on the saline ground, while near springs, where the saline matter has been gradually dissolved out of the ground, hardly any snow had melted. Where the soil is most moist or even swampy, and in river-courses, high reed-grass is abundant. The southern part of the jilga, particularly south-east of Taitma, is lowest, and here a large quantity of pure salt in small cubical crystals is collected. The fact that there is such a large quantity of saline matter, together with salt swamps in the southern part, seems to prove that this jilga at least and probably most of the others had been washed out by the sea, and that while others had gradually, though only partially, drained off the saline matter, this one retained it because it has at present no outlet. It is in fact a dried up saline lake, which at some remote time was cut off from the sea of which it was a fjord.

Jigda Jilga is occupied by about 150 to 170 Kirghiz tents; each tent may be taken as containing five souls. There are a few fields near Jigda camp, and if there has been a large quantity of snow the crops are said to prosper very well. During the winter the Kirghiz are encamped in small groups near the different springs. They do not keep many horses, but large numbers of sheep and goats and a few camels. One whole *akoi* is a light load for a camel; when packed the blankets are made into saddles over the hump of the animal.

A third jilga is south of the Belanti pass and north-east of the Nibulak pass. It is about eight miles in breadth and the same in length. There are two large water-courses leading to it from the range. On the southern side it is enclosed by Artush and gravel beds, but whether an outlet exists is not known. It has no forest, nor any kind of trees or large bushes, and the grass vegetation is scanty, evidently on account of the dryness. A southerly outlet very likely exists. We met a few Kirghiz encamped here from Ush-Turfan. The only supply of water they had was melted snow, and as soon as the snow-beds about are exhausted, they have to retreat with their flocks to the Kakshal valley.

ON THE EVIDENCES OF 'GROUND-ICE' IN TROPICAL INDIA, DURING THE TÁLCHÍR PERIOD, *by* F. FEDDEN, F.G.S., *Geological Survey of India.*

Since the announcement by Mr. Blanford in 1856 (Memoirs, Geological Survey, India, Vol. I, page 49) of the occurrence of deposits supposed to be glacial in formations occupying the low lands of India south of the Tropic—those formations, moreover, being presumably of palæozoic age—the fact has hardly engaged the attention due to one so opposed to every-day experience at present. This neglect must, of course, be in a great measure attributed to doubt. Even among ourselves, observers of the Tálchír boulder-clay have subsequently attempted to offer explanations of its mode of formation without the agency of ice. But this view never obtained favour from those having the largest acquaintance with the deposits in question, who have confidently looked forward to the confirmation of the judgment given by Mr. Blanford.

Although it had been pointed out from the first, that the mode of ice-action involved was of a kind in which striation would be the exception rather than the rule, still, striation was almost the only independent testimony to be looked for in confirmation of the general evidence. The boulder-bed had no resemblance to the till, or the deep-moraine, of a continental ice-sheet, except perhaps that the fine greenish silt so frequently forming the matrix of the boulder-bed has a great similarity to the well-known glacial mud. It was equally

unlike the ordinary moraine deposits of glaciers; the boulders exhibit, most commonly, considerable weathering or water-wear. The boulder-bed, too, is not usually a bottom bed, but is generally intercalated with very regular and sharply bedded deposits. Lamination is moreover not unfrequently displayed in the boulder-bed itself. These features all point to the familiar circumstances accompanying ground-ice, where loose materials are picked up by the freezing of the water in rivers or on the shallow margins of water-basins, and floated away to be deposited elsewhere. Even so it must happen that such ice-rafts get stranded with more or less violence, producing striation and polishing of the imbedded boulders and of the rocks with which they may come in contact, as also when urged onward by the accumulating force of an ice-blocked river. It was therefore confidently expected that sooner or later evidence of this kind would be forthcoming in the Tálchír boulder-bed.

In January 1872 I had the good fortune to find an excellent example of this missing link of evidence. The place was visited shortly after by Dr. Oldham, who dug out and removed a fine specimen of hard dense close-grained syenitic granite, of which one side is beautifully polished, scored and striated. This specimen is now in the Museum of the Geological Survey in Calcutta. Notice was given of the discovery at the time by Dr. Oldham in a foot note to a paper by Mr. Blanford on the Geology of Nágpúr (Mem. Geol. Sur., India, Vol. IX, p. 324).* The section was not then very well seen. But on revisiting the ground during the past season, I found the rocks much better exposed. A special record of the case is made, as it is not unlikely that the elements may before long obliterate what they have now laid bare. The locality is near the little village of Irai on the right bank of the Pem river, not quite a mile above its confluence with the Wardha, and ten miles to west south-west of Chánda.

The surface features of the neighbourhood for a considerable distance always form an important consideration in the discussion of any particular case of ice-scratching; and even for these most ancient deposits we are not without some plausible conjectures on this point. From the very general fact of the Tálchír group, and the other lower members of the series to which they belong, occupying low ground in the actual drainage basins, and being commonly overlapped by the succeeding members of the series, it is apparent that the actual basins are in a manner the reproduction of the pre-Tálchír ground-configuration. No doubt the ancient highlands had been greatly denuded to furnish materials for the thick deposits overlying the Tálchírs; and they must have suffered further reduction from the denudation which has for the most part removed again those overlying groups. Yet it is probable that the existing contours give an indication of the pre-Tálchír surface. If it be so, there is nothing here to support the notion of a glacier having reached the spot under notice. For many score miles round there is no commanding elevation of rock older than the Tálchírs from which an ice-stream could have descended. The supposition of an expansive ice-sheet would be still more difficult to reconcile with the observed features.

The general circumstances of the case under consideration thus lead us again to the supposition of ground-ice; and this view is remarkably strengthened by the coincidence that this single instance of scratched boulders is found in immediate connection with the only known example of a scored and polished rock-surface. The boulder-bed is here a bottom rock, resting upon compact Pem-limestones (Lower Vindhyan). For a length of 330 yards along the river's bank this underlying rock is exposed, displaying a large surface, polished, scratched, and grooved after the fashion so familiar to glacialists. The surface has a slope of 12°—15° to the west, obliquely overcutting the strata, which have a dip of 8° to west, south-west.

* Mr. W. Blanford also gave a brief notice of the fact, and of the general evidence for the existence of glacial forces at this early geological epoch in India, at the Meeting of the British Association at Bradford, 1873, Sections, p. 76.

The striæ and grooves run in long parallel lines, having directions between north-east and north-north-east, oblique to the slope of the surface; and from the manner in which the rock is affected at the edges of the few planes of jointing, it can be inferred that the movement was *up* the slope. It is, of course, not certain that the present inclination of this surface is the same as when the scoring was produced. The Tálchírs have undergone considerable crushing and displacement, though this might well have occurred in soft strata without much affecting the hard rocks against which they rest; but the actual conditions are so far confirmatory of the view we have been led to—of an ice-raft being drifted against and impelled up an opposing rock surface.

The boulder-bed itself is strongly developed in the district, especially to the north, where the contained masses of foreign rock—limestone, quartzite, granite (*pegmatite* and *protogine*) &c.—are of huge size and very numerous. In the immediate vicinity of Irai, the boulders are for the most part small, a few attaining a major diameter of 2 feet and even 2 feet 6 inches. Some of these boulders are worn smooth on certain sides only, and in the direction of the longest diameter; others more rounded have a beautifully polished surface: they are moreover striated and scored in fine parallel straight lines, precisely similar to the rock-surface above described, and resulting evidently from glacial motion or 'ground-ice.'

These boulders are enclosed in a fine gravelly bed of heterogeneous material, conglomeratic near the base, and intermingled with angular rough blocks and rock fragments.

It would appear that the freighted ice-mass had travelled a long distance from the south-west, through the Utnúr and Edlabád (Idulabad) districts, where rocks occur of the same composition as that of the several boulders.

The evidences for the glacial origin of these deposits is as conclusive as that for the ice-age formations of Europe.

The latitude of Irai is 19° 53′, elevation under 900 feet; the most southerly known position of the Tálchír boulder-bed is latitude 17° 20′, and only a little above the level of the sea.

BOMBAY,
September, 1874.

TRIALS OF RÁNIGANJ FIRE-BRICKS, *by* T. W. HUGHES *and* H. B. MEDLICOTT, *Geological Survey of India.*

Amongst other investigations connected with the projects to utilize the Indian iron-ores, some fire-bricks that were furnished by the firm of Messrs. Burn and Company were examined and tested in September last.

They were made from various clays obtained in the neighbourhood of Ráníganj and elsewhere, and were highly recommended as having stood the wear and tear of ordinary cupolas, and it was hoped that they would be found capable of standing the more heavy work of a blast furnace. It will be seen, however, from the subjoined details of my experiments, that there were some defects in their composition, and that although they were quite as good, or rather somewhat superior to the Stourbridge fire-bricks which could be procured at the time, they fell short of the excellence of Glenboig.

Subsequent trials, however, of the same kind and degree as those conducted in the first instance were made by Mr. Medlicott on bricks improved as suggested in the first report, and his verdict was "that several of them stood the test perfectly, showing no sign of cracking or of vitrification." These latter trials were made in the presence of Mr. Whitelaw, Manager of

the Bengal Iron Company's proposed work, and others, who agreed in the favorable estimate formed of the quality of these bricks.

The experiments were, with the kind permission of Colonel H. Hyde, R. E., Master of the Mint, conducted at the Mint furnaces.

Mr. Hughes, who conducted the first trials, reported—

1. "The fire-bricks tested by me were furnished by the firm of Messrs. Burn and Company, and are stated to have been made from fire-clay obtainable in the neighbourhood of Mallapúr.'

"The results of my experiments are—

"*1st.*—That the material from which they are made is very refractory, and capable of resisting high temperatures without sensibly fusing.

"*2nd.*—That the bricks, however, have failed to sustain the high character for excellence which Mr. Cowhan (the Manager of the Ránigañj Pottery Works) has attributed to them, inasmuch as they shrink on being subjected to strong firing, and show a tendency to fissure.

"*3rd.*—That compared with Glenboig fire-bricks they are inferior; but compared with Stourbridge fire-bricks they are somewhat superior.

"I attribute the shrinkage and fissuring to the texture being too fine; and this can only be remedied by the addition of a proper amount of burnt clay in coarse powder, or some infusible substance like silica. The particles of silica (quartz) must not be too fine, otherwise they may enter into combination with the clay.

"The usual proportion of raw to burnt clay is $\frac{2}{3}$ of the former to $\frac{1}{3}$ of the latter, and I believe this proportion was adopted in the manufacture of the fire-bricks from Ránigañj. It does not appear to have answered however; but this was probably due to the burnt clay having been ground up too fine. On a purely practical point of this kind, I do not like to give a decided opinion, as experience alone can determine what the proper proportions ought to be, and I would suggest that separate sample bricks be prepared, containing varying proportions of ground brick and silica, and the particles to be of varying sizes. A series of experiments carefully conducted will, I feel sure, enable fire-bricks to be made that will possess all the qualities requisite for the special purposes to which they may be applied."

12th September 1874.

DETAILS OF EXPERIMENTS.

(A).—The brick marked A was subjected to a temperature of over 3,000 Fahrt. in a wind furnace, the fuel being English coke. It was purposely broken in half.

Remarks.—The edges have stood well.

(B).—Was heated in the same furnace as a Glenboig brick, at a temperature considerably higher than the smelting point of cast-iron.

Remarks.—It cracked, and was fissured throughout.

(C).—Was submitted to conditions similar to (B).

Remarks.—It is superior to (B), but it is internally fissured. It contains an excess of alkaline earth, which has vitrified.

(D).—Was inserted in a plumbago crucible to avoid contact with the coke. This was carefully weighed and measured previous to insertion and after extraction Its tenderness was also noted.

Remarks.—The edges have resisted fusion, which is a good quality, and its tenderness was not of an appreciable amount. It contracted, however, more than I expected. The following were the measurements and weights :—

Measurement before insertion	...	$9\frac{7}{8}''$ long. $2\frac{1}{8}'$ deep.
" after extraction	...	$9''$ " $2\frac{6}{16}''$ "
Weight before insertion ...	...	... 277 tolas.
" after extraction ...	...	... $275\frac{1}{2}$ "

This brick when externally examined appears to approach in texture much nearer the required standard than any other.

(E).—Was heated like the last in a plumbago crucible. It is made of pure fire-clay.

Remarks.—I think it was too strongly burnt in the first instance, *i. e.*, before it passed into my hands. It cracked on being taken out of the furnace and deposited on a cold floor.

(F).—Was tested in the same manner as (B) and (C).

Remarks.—Like the other bricks, it exhibits fissures internally.

(G. & H).—Glenboig bricks, purposely broken, submitted to conditions similar to (B) and (C) and (F).

Remarks.—It will be observed that there are no fissures. No contraction and no softening.

In the second series of trials conducted by Mr. Medlicott, ten bricks, made at the Rániganj works, were tested with one of Stourbridge brick and one of Glenboig brick, and also one common machine-made brick. They were kept for four hours in the gas furnace in plumbago crucibles—for the last two hours at the full blast. None showed any sign of fusion. The machine-made brick and the Stourbridge brick were badly cracked, and one of the Rániganj bricks slightly so. The loss of weight was very marked in the Glenboig brick ; next so in the Stourbridge, probably due to the coarser texture of the former, and in both to their having been less well dried than the others.

Five of the bricks were put into a coke furnace with a Glenboig brick, and five in a second furnace with a Stourbridge brick. The former furnace seems to have been most heated: even the Glenboig brick bent and broke, and showed as much vitrification as the others. In the other furnace, all were more or less damaged—the Stourbridge least so.

GEOLOGICAL MUSEUM, }
January 1875. }

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January 1875.

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BARRANDE, JOACHIM.—Systême Silurien du centre de la Bohême, Part I, with plates, Supplement to Vol. I, and Vol. II, pt. 3, (1872-74) 4to., Paris.

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BRAUNS, D.—Der Obere Jura im nordwestlichen Deutschland, (1874), 8vo., Braunschweig.

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GREENWOOD, HENRY.—A manual of metallurgy, Vol. I, (1874), 8vo., London.

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